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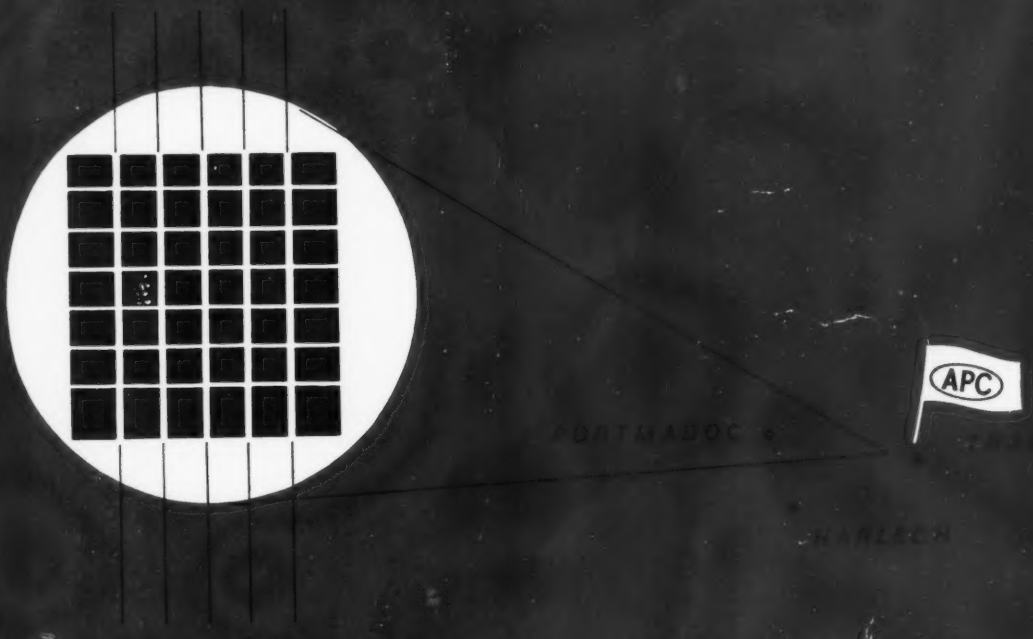

At Trawsfynydd in North Wales . . .

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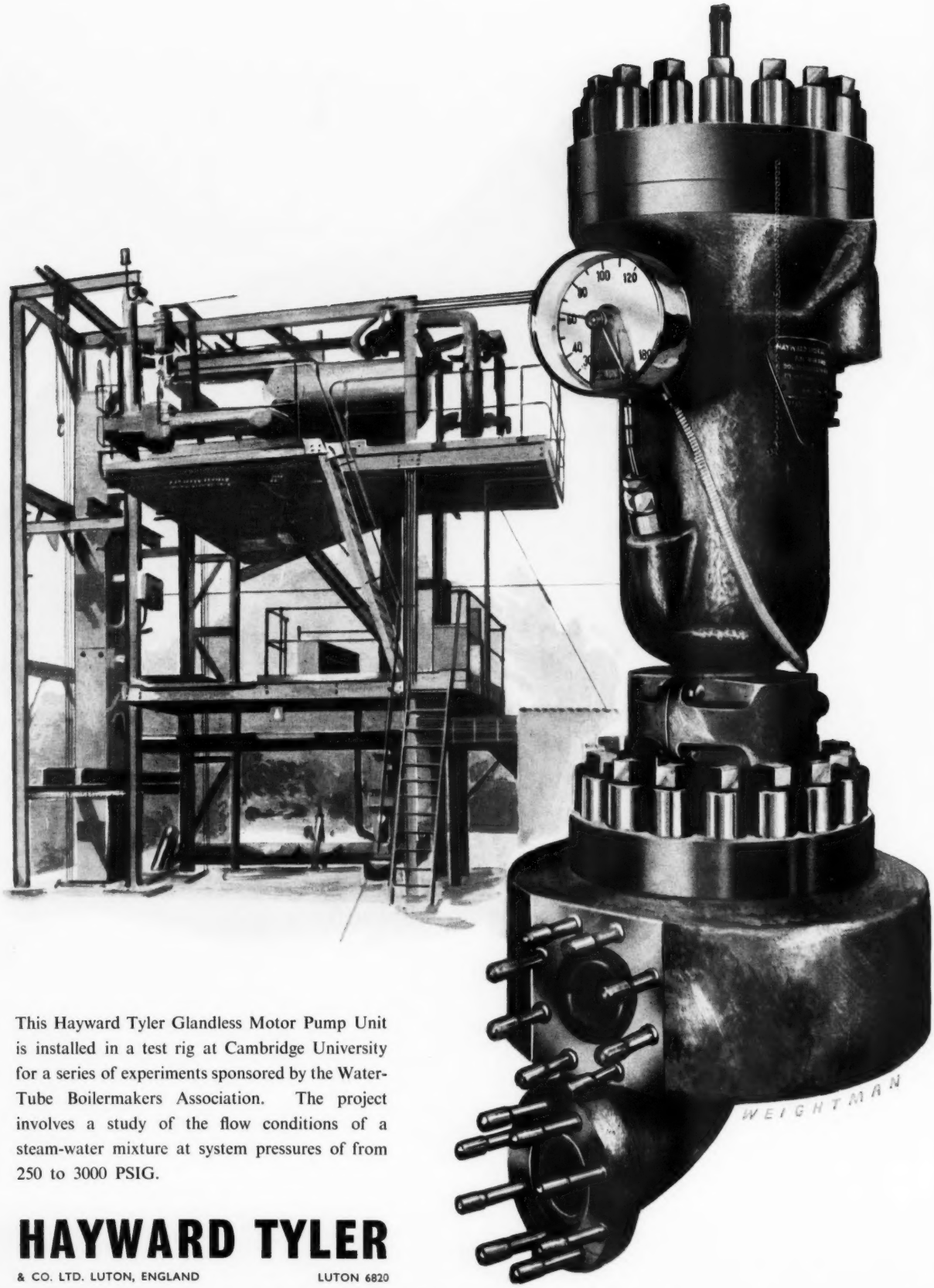

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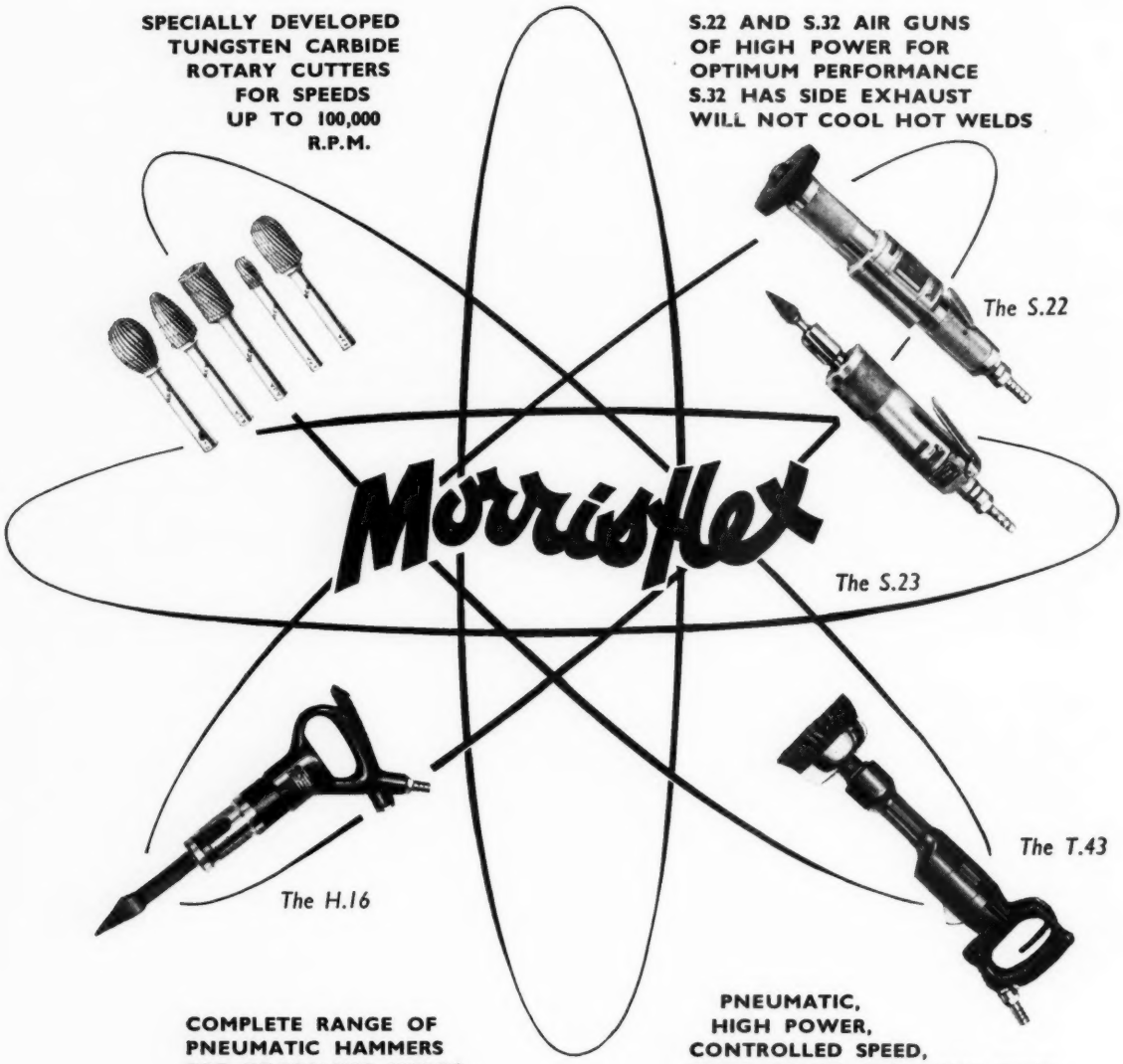

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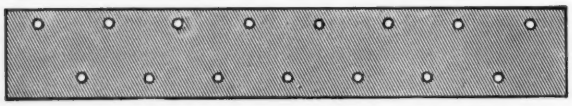

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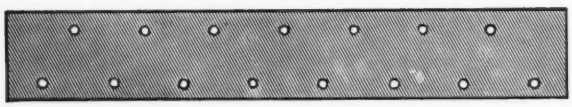

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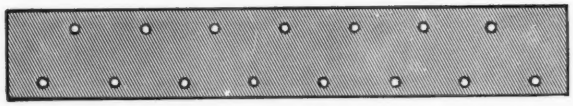

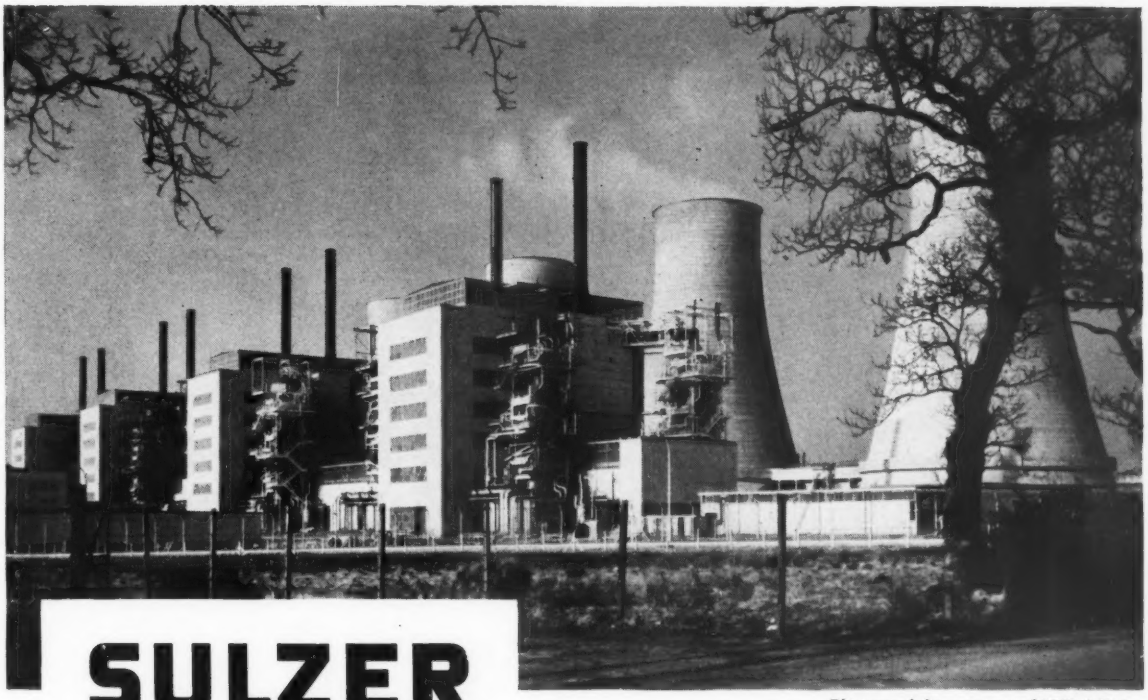

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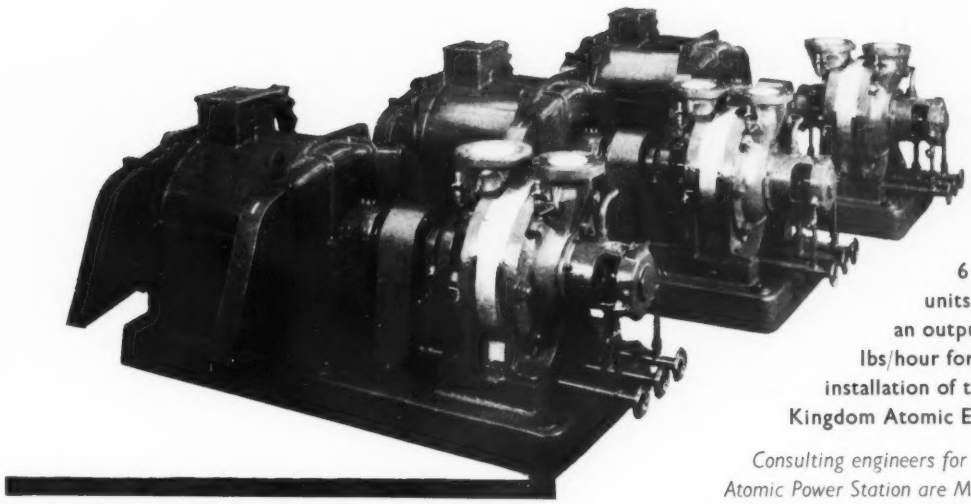

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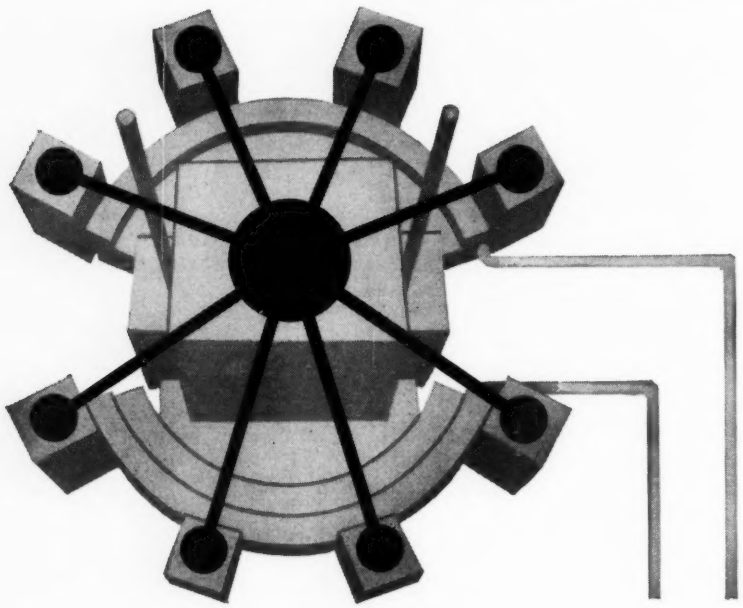
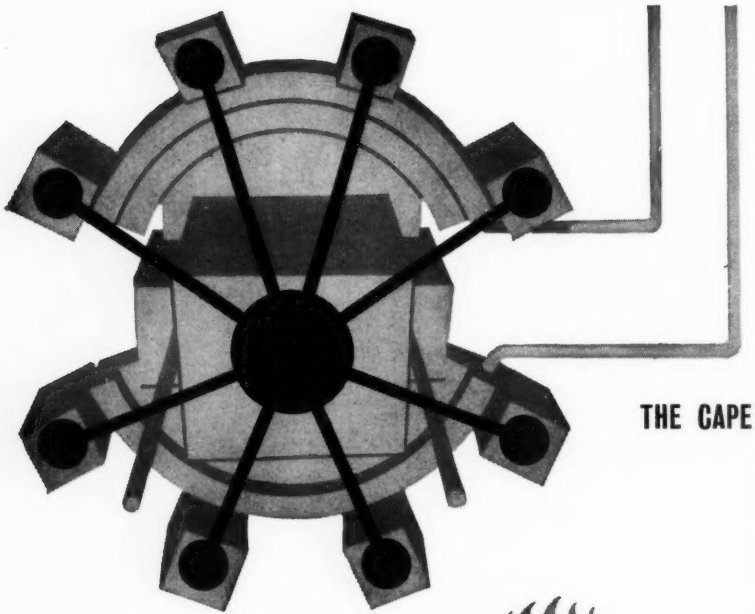


BERKELEY—a challenge to insulation



The heat developed by the twin reactors of the new Berkeley atomic power station poses problems of thermal insulation which will require new techniques in their solution. Confining and controlling such intense yet precious thermal energy constitutes a challenge—a test worthy of the knowledge and skill acquired in 65 years' experience of thermal insulation manufacture by The Cape Asbestos Company, to whom the contract has been entrusted.

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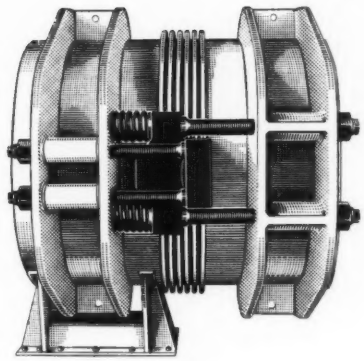

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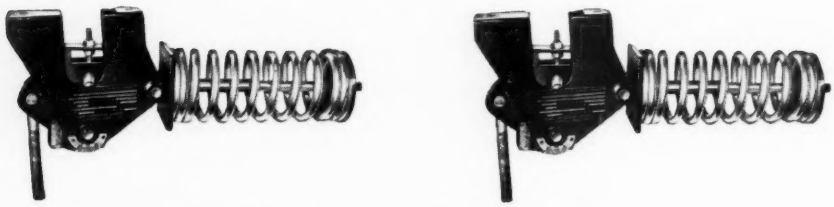

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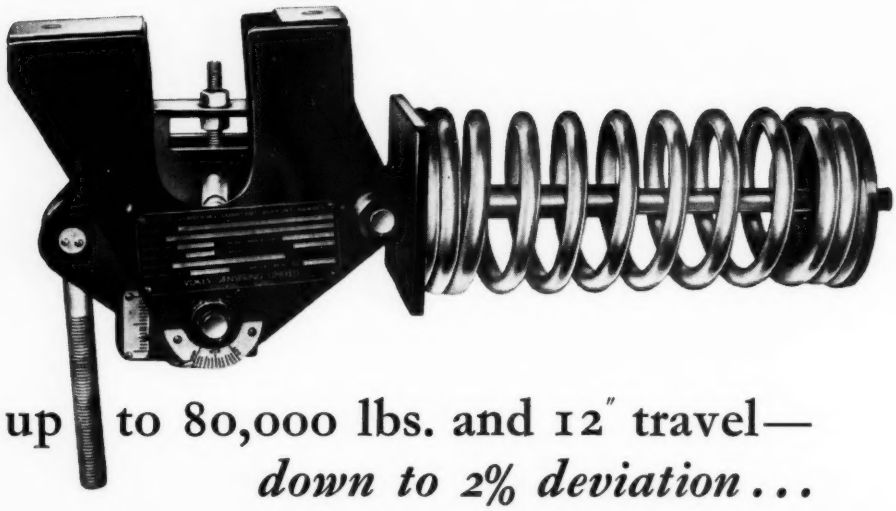

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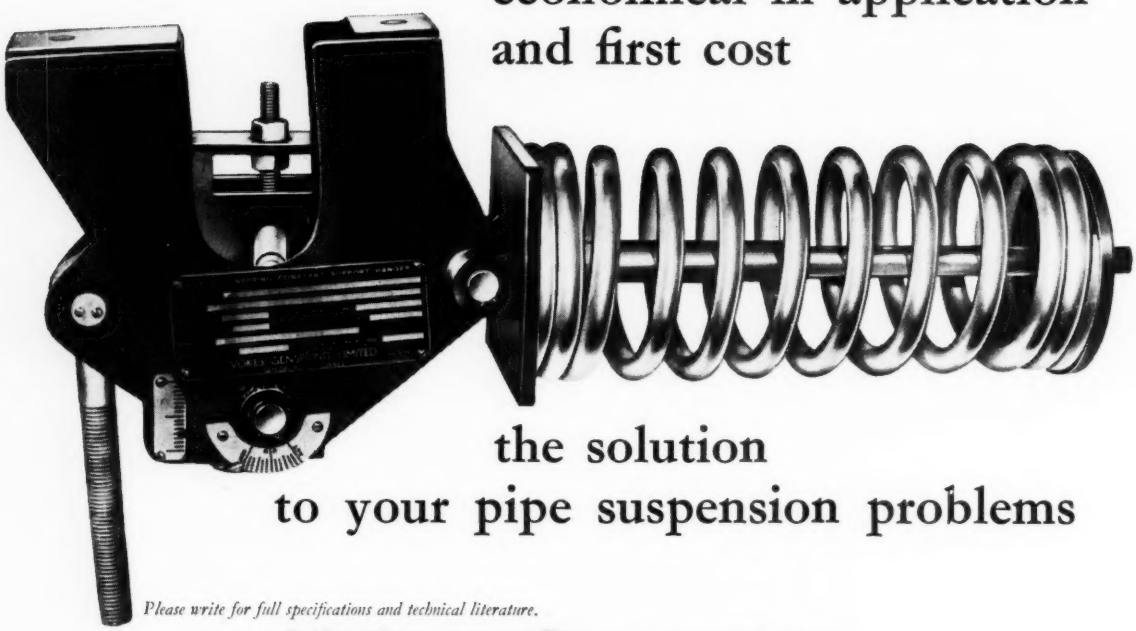

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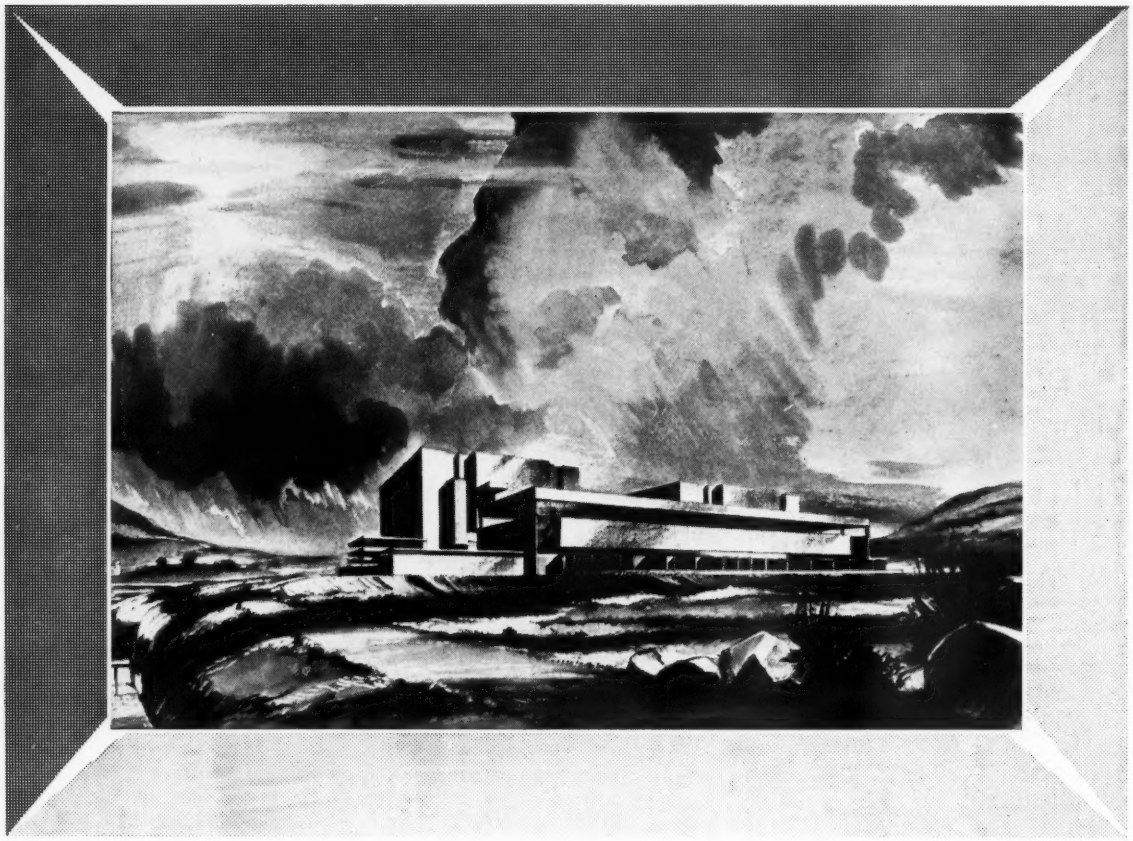

Generating Plant for Trawsfynydd

The whole of the generating, condensing and feed heating plant as well as the CO_2 circulators for the 500 MW Nuclear Power Station to be built by Atomic Power Constructions Ltd., at Trawsfynydd in North Wales, will be made by the Richardsons Westgarth Group.

THE TURBO-ALTERNATORS, four in number, each with an electrical output of 145 MW, will be four cylinder machines of Brown Boveri design for a 65 per cent high pressure; 35 per cent low pressure steam cycle. The steam conditions at the turbine stop valves will be; H.P. 927 p.s.i.g. 715°F; L.P. 290 p.s.i.g. 685°F. Each turbine will discharge through six exhausts into twin condensers.

CONDENSING AND FEED HEATING PLANT. In addition to the eight turbine condensers, The Richardsons Westgarth Group are supplying the complete feed heating plant and also two dump condensers, each capable of handling 6% of the full heat output of one reactor.

THE TWELVE AXIAL-FLOW GAS CIRCULATORS will be of a new type designed and developed by the Group Engineering Division, and will be fitted six to each reactor at the lower ends of the boilers where they will handle CO_2 at approximately 240 p.s.i.g. Each circulator will be driven by an induction motor of approximately 6,000 h.p. at a constant speed of 2,950 r.p.m., the gas flow being regulated by throttle valves in the main gas ducts linked to bypass valves in the re-circulating ducts.

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RADIATION and AGRICULTURE

PART I

by

F. R. PAULSEN, BSc, PhD, FRIC, FCS

POPULATION increases have always outstripped agricultural production, with the result that there are in the world today, just as there have always been, countless souls living at or even below subsistence level, in spite of the advance of science and human enlightenment. The cynic might say, and with some justification, that while foodstuffs are burned in some countries to keep prices up, people are starving to death in others. Whether or not such anomalies will ever be removed only time can tell, but it is a fact that never in the history of mankind was so much human endeavour and ingenuity exercised in the rational production of food commodities. Rule of thumb methods are being replaced by scientifically designed techniques, and more and more weapons are brought out of the research workers' armoury to combat famine and crop destruction by weather and organic pests and diseases. Foremost among the newer weapons, and surely the most inspiring and exciting in its success, has been atomic energy.

Radiations have been applied to the study of soil chemistry and physics, fertilizers, plant nutrition and growth control, animal and plant physiology, microbiology, plant pathology and entomology, radiation biology and genetics, and food preservation. The radiations have been applied by virtue of two important properties. First, many radiations are derived from atoms which are disintegrating, but of which the chemistry is the same as stable stoms of isotopic elements. Consequently, these unstable atoms, which are readily detected, may be used to accompany the stable isotopes in all their changes, behaving in other words as "tracers." "Tagged" and "labelled" compounds have shown immense value in all the fields mentioned above, and this article aims to produce evidence of this. Secondly, radiations have been used to produce effects which are dependent on the disruptive action which they have upon chemical processes and molecules. Such properties find their principal value in disinfestation, sterilization, food preservation, and plant genetics.

Isotopes have many uses in agricultural and horticultural research—as tracers to help scientists learn about the metabolism of plants and animals, as means of improving and producing healthier and more productive plants and new breeds, and as destroyers of pests and disease. The two illustrations on this page are of experiments in this field being carried out at the UKAEA Radiation Laboratories, Wantage

Photos : UKAEA

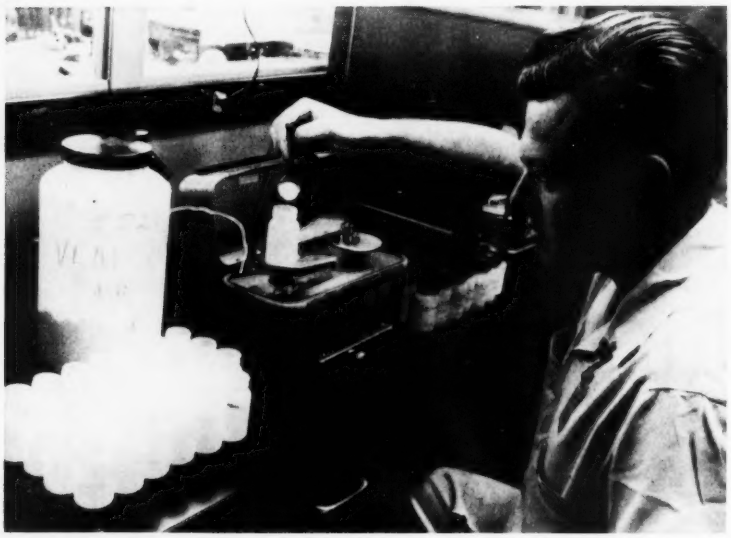
Tracer Work

Considering first the uses of tracers, much work has been done on the uptake of minor elements by plants. This has a profound bearing on plant metabolism and physiology, and on the formulation of effective fertilizers. The isotope P32 has given a great deal of information upon phosphorus uptake and the behaviour of various phosphate fertilizers.

Typical of tracer studies in this field are those incorporated in the

work of the U.S. Department of Agriculture at their research centre at Beltsville, Maryland, near Washington. Questions dealt with under these studies include:—How much phosphorus is required by a plant, and when should it be given? What is the value of the water-insoluble phosphorus in soils? Should the fertilizer be used as granules, powder, sprays, or in irrigation water? Should it be applied to the soil, or to the leaves of the plant?

It has become abundantly clear from the department's work that each plant and each type of soil has its own particular problems that have to be solved individually.



Uptake of radioactive materials by plants and animals must be accurately checked. Here a chemist weighs bone ash containing strontium-90, at a United States Atomic Energy Commission Laboratory

Thus, maize utilizes a high proportion of fertilizer phosphate at very early stages of development, but little at later stages. Maize develops a very extensive and deep root system, so that after its first period of growth, the root system is too deep to enable the phosphate fertilizer to be utilized. The application of phosphorus at planting time increases the growth rate, but does not increase the grain yield.

To Beat the Drought

Cotton is a typical shallow feeder. If heavy rooting could be induced in such crops, even to the extent of making the root system 12 in. deeper, the effects of drought would be much less marked. Sugar-beet and tobacco are also deep rooted, and behave in the same way as maize. Potatoes, on the other hand, require phosphorus throughout their period of growth. Grasses (including the cereals) absorb phosphorus deposited on their leaves as well as through their roots. Hence, old pastures may be rejuvenated without recourse to ploughing. In the case of those plants using the fertilizer only in their early stages, the application of phosphorus at later stages is largely wasted.

Availability of Phosphorus

Phosphorus in the form of phosphoric acid dissolved in the irrigation water is found to be just as effective as a fertilizer as superphosphate and apatite. A great deal of the phosphorus presented to a plant in a fertilizer is rendered unavailable to the plant, except very slowly, and it becomes fixed in the soil; this effect depends on the acidity of the soil. The plant however makes use of the soluble phosphorus and displaces an equilibrium, which results in more of the insoluble or fixed phosphate being solubilized, and thus rendered available to the plant.

Need for Elements

The requirement of a plant for various elements varies with the plant's growth stage. Thus, different elements are required for different relative amounts of them, at least for stem and leaf growth, flower production, and fruit and seed development. In the case of strawberries, for instance, phosphorus concentration is high in the seed, while in the apple the concentration of both phosphorus and magnesium in the developing seed may be so great that the leaves from which the supplies are drawn may become magnesium deficient. Thus, the situation arises, that of the applied phosphorus, 95 per cent. may be taken up by leaves, while only 5 per cent. to 10 per cent. may be obtained from soil.

Influence of Soil

When superphosphate is added to the soil, the proportion of the phosphorus uptake is inversely proportional to the relative fertility state of the soil, though unrelated to the dry weight of tissue. When hydroxyapatite is used as the source of phosphorus, much the same is found, except that utilization is considerably lower than is the case with superphosphate. The concentration of P32 tracer in the soil changes at first logarithmically with respect to time, showing a first order reaction which is probably a surface exchange. Later the change is linear with time, this being a second reaction which is at present little understood.

Isotopes such as Ca45, S35, Zn65, K42, C14 and Co60 have also been used for studying the ion exchange properties of soils in relation to fertilizer utilization. In particular, P32 has found application in the study of root penetration without disturbing the plant functions.

Some rather unexpected results have sometimes been obtained from tracer studies. For example, it has long been thought that plant sap is virtually stationary in winter, yet work with radio-potassium has shown that the sap is in movement throughout the hardest winters. Radio-potassium, when applied to dormant buds, is taken into the tree, and passed up and down the trunk for a distance of several feet. Californian fruit-growers have long been in the habit of spraying their fruit trees with zinc during the dormant period, and the habit now receives some justification.

The absorption of plant nutrients has been shown to be not simply

Radioisotope solution is mixed into crushed phosphate rock to produce a tagged fertilizer

a one-way process. If plant roots are immersed in a labelled nutrient solution, and then transferred into a solution containing the untagged nutrient, absorption of the nutrient element still continues, but the radioactive element finds its way into the solution. This, of course, points to a reversible absorption. The longer the labelled element has been absorbed into the plant, the less easily does it exchange with the unlabelled element. In copper-deficient soil, iron is abnormally accumulated in the nodes of the plants, but the addition of copper restores the condition to normal.

Internal Movements

The plant leaf has been shown to be a very efficient absorber. Materials can be taken into both the upper and the lower surfaces of the leaf, both by day and by night. The leaf surface of a 12-year old tree has been shown to be ten times that of the soil surface occupied by the tree. Calcium applied to the leaves does not readily reach the roots, but soil calcium readily passes up through the plant. It is not surprising, then, that the daughters of a strawberry plant can starve, as a result of calcium deficiency, if calcium fertilizer is applied only to the leaf surface of the parent plant.

The fertilizing value of urea has been fairly extensively studied by tracer methods. Cucumber plants make use of it rapidly, but can tolerate concentrations only up to 3 lb or 4 lb/100 gal. Plum and peach tolerate concentrations up to 20 lb/100 gal, but absorb the urea only slowly. Tomato and maize show intermediate behaviour.

On irrigated calcareous soils, the solubility of fertilizer iron is low, the calcium and bicarbonate ion concentrations being high. Consequently, chlorosis of plants is common under such conditions.

Photosynthesis is highly complex, and one of the processes in which nature proves herself a supremely capable chemist. The various stages occur very rapidly, and have consequently puzzled the biochemists for many years. By means of radioactive tracers it has now been possible to obtain a reasonably thorough understanding of the synthesis of carbohydrates in the living plant, and of many other metabolized products.

Several isotopes have been used to study plant metabolism, C14 and tritium being typical examples. Studies have included the movement of water and organic materials in the plant, sugar metabolism, utilization of plant hormones, foliar absorption of nutrient elements, organic biosynthesis, the effects of metals on plant diseases, and the photosynthetic processes.

Plants kept in an atmosphere of $C^{14}O_2$ are found to contain radioactive carbon within 1 min and about 50 labelled carbon compounds are found in the leaves. Even after 2 sec of exposure to light, two or three compounds of labelled carbon are found in the leaves, and these include phosphoglyceric acid derivatives. After 2 min exposure, radioactive fats and proteins can be identified. The sunlight is absorbed by the pigments in the plastids of the leaf and converted into chemical energy. Water transfers its hydrogen to other materials which are able then to reduce carbon dioxide into metabolized compounds.

One of the first sugars synthesized is the seven-carbon molecule sedoheptulose. In subsequent stages this is degraded into a pentose and a two-carbon compound, the latter combining again with carbon dioxide to give the heptose. The pentose is broken down into molecules with three and two carbon atoms, the latter again being converted into heptose by CO_2.

Ion Mobility

Work on the metabolism of nitrogen has yielded some unexpected results. It has been shown, for example, that pipecolic acid is derived from lysine in the plant, and that in the non-green potato nitrogen is converted into glutamine and aminobutyric acid. The mobility of the ions varies considerably with the nature of the ions. Thus, sodium, potassium, phosphorus, chlorine and sulphur are very mobile, and calcium, strontium and barium are immobile.

A scientist makes an exploratory test with a Geiger counter to detect uptake of phosphorus-32 in tagged fertilizer experiments at Rothamsted Agricultural Experimental Station

(Crown Copyright Photograph)

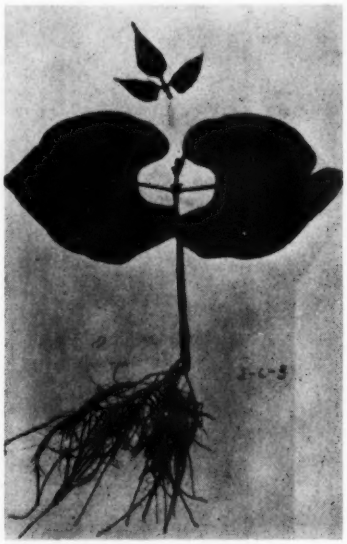
Zinc, copper, manganese, iron and molybdenum are in an intermediate group. The immobile ions travel only in the direction of the transpiration stream, but the mobile ions can move in all directions.

In the fixation of nitrogen by micro-organisms, glutamic acid appears to be readily formed. Fresh organic matter added to soil increases the decomposition rate for soil organic matter during the first few weeks, but then slows it down.

Plant Hormones Traced

Radioisotopes have been used extensively to elucidate the mysterious behaviour of substances which control plant growth. At the Argonne National Laboratory of the U.S. Atomic Energy Commission gibberellic acid, one of the natural growth hormones, has been found to lengthen stems and leaves, to increase fruit yield, and to act as a substitute for daylight or warmth in the processes of germination and flowering. The substance, discovered in a Japanese fungus, appears now on the market as a white powder which can be applied in the form of sprayed solutions. When samples of sugar labelled with C14 are fed to the fungus, the gibberellic acid isolated proves to be radioactive. The substance induces response in many plants, among which are beans, hemp, lupin, sunflower and tobacco, and it produces larger fruit clusters in the vine. Unexpected results are produced in the hemp, in which male and female flowers are usually borne on different plants. The application of gibberellic acid to the female hemp plants also induced the formation of functional male flowers. As little as 10^{-9}g. of the substance proves effective, and its effect on animals is apparently negligible.

Photograph of a leaf taken at Brookhaven National Laboratory, U.S., after radioactive phosphorus-32 had been taken up by a coles plant. P 32 accompanies ordinary phosphorus food through the veins of the leaf. After the leaf has been placed against photographic film, the film is developed. Beta rays emitted by the P 32 leave light traces against the dark outline of the leaf as a whole. Photos of this kind can shed light on the concentration of phosphorus necessary to maintain a healthy plant under various conditions



The illustration on the left is a photograph of a dried pinto bean plant to which a small amount of carbon-14 labelled, gibberellic acid, has been applied through the base of the large primary leaf on the right side of the plant. The illustration on the right is an autoradiograph of the same plant indicating the distribution of radioactivity after 3hr since application of the tracer. Some radioactivity can be seen to be present in the roots

Among the growth regulators, one of the most effective is α-methoxyphenylacetic acid (MOPA), which operates in the cycle: plant-soil-plant. A typical thinning-out agent is the related compound napthalene acetic acid or NAA.

War Against Weeds

Broad-leaved plants absorb sprayed weedkiller completely within 2 hr, whereas the grasses and other narrow-leaved species absorb only a very small amount, and this does not spread in the plant. This discovery led to the use of selective weed-killers for use on lawns and cereal crops.

Isotopes have also found considerable use in the war against insect and other pests, which are responsible for astronomically high losses each year. Movements of insect pests have been monitored by labelling them with isotopes such as Co60 and P32, so that the life cycle and feeding and breeding habits can be studied. In the isotopic dilution technique, a number of radioactive insects are liberated, and subsequently their incidence among the species population is determined. This gives an indication of the total population of the insect. Insects can be fed on labelled materials and their movements tracked over wide areas. This technique has been applied, for example, in studying the insect-spread virus of swollen-root in West African cocoa.

Naturally, work with radioactive isotopes is not completely free from hazards, and certain precautions have to be taken. For example, at the Beltsville Centre, mentioned above, P32 is incorporated into fertilizers, which have to be ground in special hooded mixing machines.

Long-handled tools, gloves, respirators, and dosimeters are also regularly employed. The isotope is prepared by the neutron irradiation of potassium dihydrogen phosphate (KH_2PO_4) for 24 days, the half-life of the P32 being 14.3 days.

Biosynthesis Used

Biosynthesis is frequently used in the preparation of radioactive samples of organic plant materials. A typical installation is the " isotope farm " of the Medical College of

(*Continued on page 495*)

- **3½ in. Thick Pressure Vessel**
- **Simple, Cheap Coolant Control**
- **Improved Core/P.V. Ratio**

TRAWSFYNYDD Design Features

THE 500 MW nuclear power station being built at Trawsfynydd, North Wales, is the second one of this capacity in Britain. In design and potential performance it represents an even greater advance on the earlier commercial Calder Hall type stations than the 500 MW station now taking shape at Hinkley Point, Somerset.

Like the Hinkley Point station, Trawsfynydd will have two natural uranium, graphite-moderated, gas-cooled reactors. Improvements made in the design will increase the station's efficiency and reduce capital and operating costs. For instance, Hinkley Point is estimated to cost in the region of £55m., Trawsfynydd £50m.

The performance of a nuclear station depends upon the cumulative effect of a series of independent processes. Improvements in overall efficiency are brought about by redesign of components and equipment in these separate parts. No fundamental technological changes are involved.

Improved Heat Rating

Prominent among the improvements in the Trawsfynydd design is the increase in the thickness of the walls of the pressure vessels. With the help of improved welding techniques it will be possible to fabricate these vessels with 3½ in. thick plate and so enable coolant gas pressures higher than those possible in 3 in. thick vessels to be used. Coolant gas in the Trawsfynydd reactor vessels, each of which will be 61 ft in diameter, will be kept at a pressure of 240 lb/sq.in. gauge. The effect of higher gas pressure will be to reduce pumping power at the blowers and bring about an improved heat transfer.

It is worth mentioning here that the use of 3½ in. thick plate necessitates the radiographic examination of welds by means other than X-ray if exposure times are to be kept as low as possible. Quicker exposures than possible by X-ray would be feasible with either a radioactive source, such as cobalt-60, or a linear accelerator.

Linked Valve Control

Another significant improvement in the Trawsfynydd design is to be found in the control of the coolant flow. There is to be a constant speed circulator drive consisting of an induction motor running at 2,950 rev/min directly coupled to the blowers. Regulation of the coolant gas will be effected by means of linked butterfly valves in the main gas ducts and return ducts. This method of control is simpler and cheaper than using variable speed motors or turbines as planned for other stations. Before incorporating it in their design, however, Atomic Power Constructions had to find ways of overcoming the objections associated with the linked valve system, objections made on grounds of safety.

One other feature of the Trawsfynydd design worthy of special mention is the improved ratio of core volume to pressure vessel volume. The more graphite that can be placed within the vessel so the pumping power of the blower can be reduced and better heat transfer effected.

The graphite moderator which makes up the bodywork of the core will be a 24-sided structure measuring about 48 ft across the flats and 27 ft 6 in. in height. The graphite will be in the form of specially machined blocks and tiles held together by circumferential members.

The ability to put more graphite inside the vessel has been due to the use of specially designed structure for supporting the core. This consists of a fabricated steel grid carried on pillars and struts from the inner skirt of the vessel. The use of a greater mass of moderating graphite has not, incidentally, handicapped the provision of fuel handling machinery.

The moderator contains 3,730 fuel element channels arranged on a 7.75 in. lattice pitch. There are additional channels for control rods and also some standpipes. Any of these can be used for taking control rods too, so giving a flexibility in the number and arrangement of control rods.

The Fuel

The fuel elements will comprise natural uranium encased in magnesium alloy cans. Extended fin surfaces will give improved heat transferences, a factor which coupled with the higher up coolant pressure will contribute to improved reactor ratings.

The elements will be stacked in the channels on top of each other so as to give a total length of uranium in each channel of just over 20 ft. This length has been found, by careful optimization of all the factors involved, such as coolant temperatures and pressures, core dimensions, lattice pitch, element details, etc., to give the best heat transfer results. The fuel elements will be kept in the centre of the channels by means of four longitudinal alloy splitters fitted on the sides of the can.

Graphite sleeves round the fuel elements will help to raise the temperature of the lower part of the moderator and so reduce the build-up of Wigner energy.

Elements will be loaded into the reactor core and removed from it by means of special charging machinery

while the reactor is operating. The charge machines will be about 64 ft high and weigh about 380 tons. These machines will be moved about on the reactor cap by means of overhead cranes. Facilities for their maintenance will be made available at charge face level.

Heat is removed from the core by means of six 5 ft 6 in. ducts that take the coolant to the boilers. There are six of these to each reactor. Each one has an internal diameter of 18 ft and height of 116 ft and is fabricated from $2\frac{1}{2}$ in. thick steel plate.

Dual Steam Cycle

A dual steam pressure steam cycle has been adopted for the station, the boilers generating 65 per cent. of the steam at a high pressure. Steam conditions for the two systems are as follows:—HP steam—927 lb/sq.in. gauge, 715°F.; LP steam—290 lb/sq.in. gauge, 658°F. All boiler tubing is fitted with external resistance welded fins in order to improve the heat transfer on the gas-side.

Carbon dioxide is returned to the reactor from the boilers by means of single-stage axial-flow fans fitted below the boilers. Power consumption of each blower is about 6,000 h.p.

Each reactor and its set of boilers will be housed in a building measuring 300 ft long × 180 ft wide and 179 ft high. The boilers with associated gas ducts will be individually shielded by means of extensions of the reactor biological shielding. The shielding is designed to the specifications of the latest safety regulations. At boiler plinth level the reactor building will be extended to form a common blower house containing electric motors for each of the blowers.

Control and Safety

Control of the station during normal operation will be carried out from a single central control room. There will be two automatic control loops external to the reactor, one primarily intended for the elimination of instabilities in the reactor neutron flux and the other for regulation of reactor output to meet load demands.

All possible safety measures have been included in the design including special emergency shut-down devices.

The station's generating plant will consist of four 145 MW four cylinder turbo-generators designed for dual pressure working. The steam will be discharged from each turbine into twin condensers. The generators will have water cooled stator windings. They will be housed in a 450 ft long, 220 ft wide building alongside the two reactor buildings.

Output from the turbo-generators will be fed to transformers to step up the voltage to 275 kV. The rating of these transformers will be 157 MVA. From the transformers the electricity will be fed into the Central Electricity Generating Board switching compound and from there into the national super grid system.

Facilities will be provided for an auxiliary power supply for use in breakdowns and other emergencies.

The condensers associated with the turbo-generators will be cooled with water drawn from Trawsfynydd Lake. The water will be circulated at the rate of 35m. gal/hr. It will be returned to the lake for natural cooling. This is the first instance of a lake being used as the source of cooling water for a power station in the United Kingdom. Probably the best known example of lake water cooling is at the Velmont Plain, Colorado, power station.

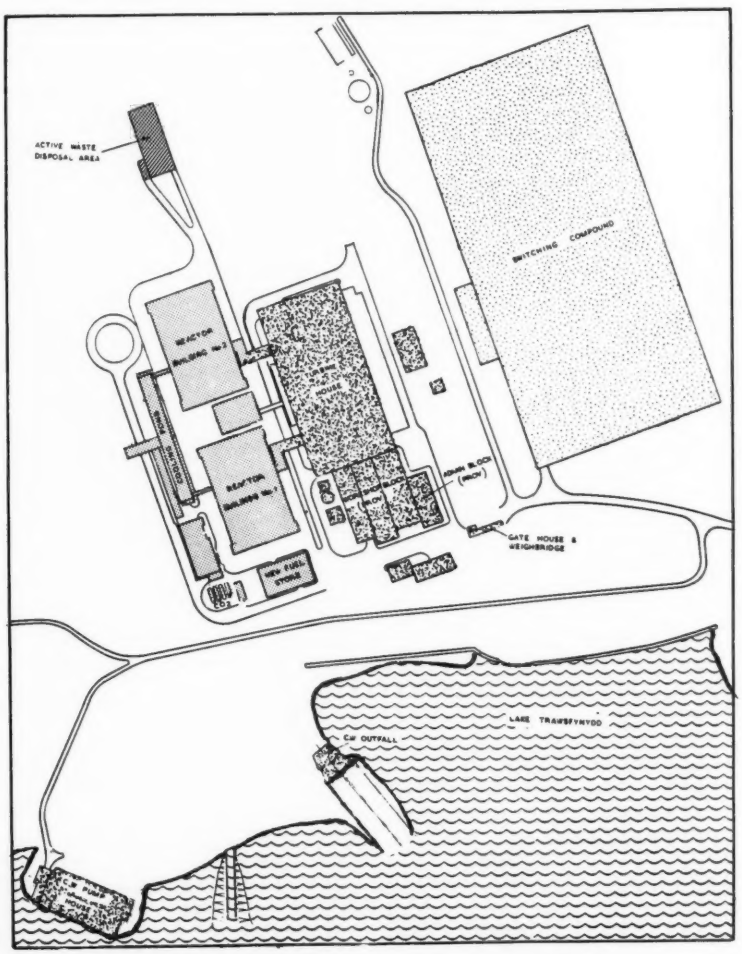
In National Park

The layout of the Trawsfynydd station is compact, not one of the least factors acting as an incentive to keeping it compact being the fact that variations in the natural level of the site exceed 50 ft.

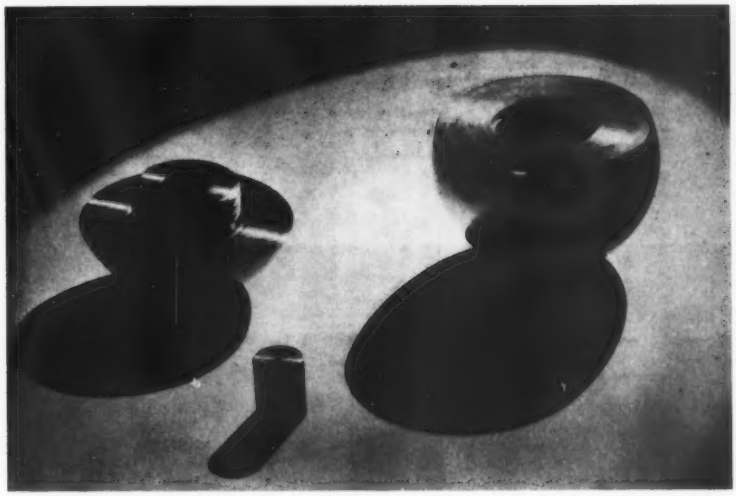
As far as is possible the station buildings have been designed to blend with the natural scenery of the area, which is part of the North Wales National Park.

The site is over 600 ft above sea level on a rocky terrain and the first work to be undertaken involves the levelling of this terrain, including a

(*Continued on page 514*)



Provisional layout of the Trawsfynydd Power Station buildings



The National Neutron Standard developed and maintained by the U.S. National Bureau of Standards consists of a beryllium sphere which contains a capsule of radium

Neutron Research

The neutron is an electrically neutral elementary particle which plays an essential role in many vital nuclear processes. It is for example, the key particle in nuclear fission. But understanding the properties of the neutron and the way it interacts with matter is essential not only for this one application but also for research into other fields such as controlled thermonuclear reactions. The effective use of high-energy accelerators and nuclear reactors in research also depends upon sufficient information on the neutron, as does the application of slow neutrons to the treatment for cancer, a therapy now only in the experimental stage. This article describes some of the work carried out by the U.S. National Bureau of Standards on neutron research.

TO ensure the safe and effective use of neutrons the United States National Bureau of Standards several years ago established a small programme in neutron standards. As the requirements of research and industry have changed over the years so the emphasis of this programme has been shifted.

At present the Bureau's research in this area is carried out by the neutron physics section, established in 1957, under the direction of R. S. Caswell. Attention is being concentrated on the establishment and maintenance of standards of neutron source strength and thermal-neutron flux, studies of neutron penetration and slowing-down, measurement of neutron and gamma-ray dose in radiation fields, and investigations of improved neutron detectors.

In recent years, the number of neutron sources throughout the world has greatly increased, and the demand for precise measurement of neutron-radiation fields for protection of personnel has correspondingly become much greater. However, detection and shielding are complicated by the fact that neutrons, because they lack electrical charge, have few interactions with matter, particularly with the electrons of atoms. Neutrons, however, do react with atomic nuclei, and must therefore be detected indirectly by means of other particles which result from these interactions. Such particles might be, for example, recoil nuclei from "billiard-ball," or elastic, collisions, or alpha particles ejected from nuclei which have absorbed neutrons.

More Accuracy Needed

Although detection equipment and film badges for personnel monitoring are now extensively employed in the areas of accelerators and reactors, there is still need for improvement in measurements of neutron-radiation dose. Such measurements are complicated by the presence of gamma-radiation in all neutron fields. To make possible more accurate neutron dosimetry, the Bureau has extended its 35-year-old programme in X- and gamma-ray dosimetry to handle the problems presented by mixed neutron and gamma-radiation fields.

Accuracy of all neutron measurements is ultimately dependent on the reliability of standards. In line with its basic functions, the Bureau therefore calibrates absolutely and maintains the national standards of neutron source strength and thermal-neutron flux. Laboratory standard neutron sources are calibrated for universities, industrial experimental stations, and other government agencies for use as secondary standards in fundamental nuclear-physics experiments, measurements of nuclear-reactor behaviour, problems of neutron-radiation protection, and industrial applications of neutron beams. In addition to source calibration, neutron fluxes in nuclear reactors are calibrated by activating gold or copper foils and counting against foils activated with a standard thermal-neutron flux geometry.

A basic understanding of neutron shielding is needed in designing shields for nuclear reactors and for particle accelerators such as cyclotrons and linear resonance accelerators, where the neutron shielding problem is often an outstanding

consideration. Experiments in neutron penetration are carried out by the Bureau to check neutron shielding theories. The theories can then be applied to the design of light-weight, high-efficiency shields for mobile reactors, employed in nuclear-powered aircraft, ships and submarines. Particularly in the case of the nuclear-powered aeroplane, the weight of a conventional shield, such as concrete, is prohibitive.

Other experiments are concerned with precise measurements of the neutron " age " in reactor moderator materials such as water and heavy water. The " age " is a measure of the penetration of neutrons during the slowing-down process, and is an important constant for determining the leakage of neutrons from a reactor.

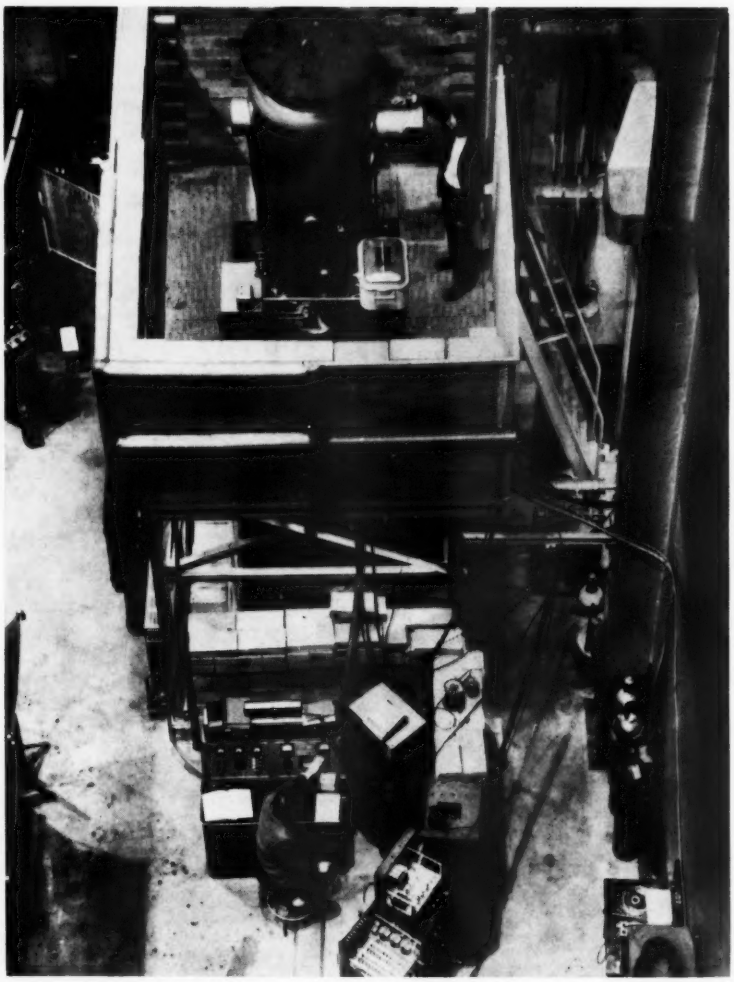
" Cross-Section " Measured

A fundamental approach to neutron problems is the direct measurement of the " neutron cross-section " —the probability of a neutron undergoing a certain nuclear reaction with a given nucleus. A programme aimed at measuring these interactions is under way.

In the late 1940s, two nearly identical radium-beryllium neutron sources were constructed to serve as standards of neutron source strength. Each source consists of a capsule of 1 gm of radium in the centre of a beryllium sphere, 4 cm in diameter. One source, NBS-1, serves as the " National Neutron Standard." The second source, NBS-2, is loaned to other laboratories for the purpose of comparisons. It was recently sent to England and to Sweden.

Types of Sources

In the past, most national standard neutron sources have been radium-beryllium (α, n) sources, made by mixing a radium-containing powder with beryllium powder. Although these sources have high neutron yields, they are not completely satisfactory because the neutron strength increases with time as radium decays to polonium. Any change in state of the mixed powders can lead to a change in neutron emission rate, which is, of course, undesirable in a standard source. The capsule-in-sphere radium-beryllium (γ, n) source overcomes this problem as neutrons are produced only by the gamma-rays from radium acting on the beryllium in the spherical shell.



The low-scatter room at the U.S. National Bureau of Standards

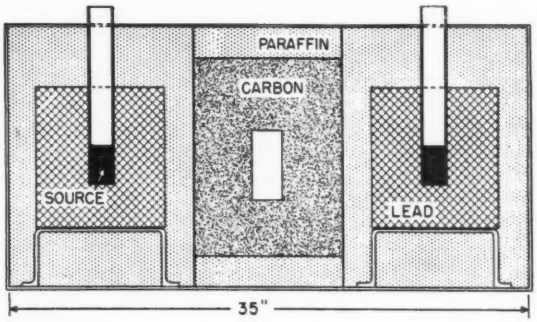
While these photoneutron sources are very well suited for standards, they are inconvenient to work with in some laboratory situations because of intense gamma-ray emission. More acceptable laboratory standard sources are plutonium-beryllium (α, n) sources, which have been made available by the U.S. Atomic Energy Commission. This type of source, which provides low gamma-ray emission and long half-life, sometimes is used as a working standard at the Bureau.

International Agreement

The NBS standard neutron sources have been compared, either directly or indirectly, with the national standard neutron sources of all countries known to maintain sources, including the U.S.S.R. All of these sources are in agreement to within about 2 per cent. of the international mean value.

The " National Neutron Source " has been calibrated absolutely in two different ways. The first, and most tedious, method involved the measurement of a thermal-neutron density in a water tank surrounding the source. In the idealized situation, the water tank is large enough so that it can be assumed no neutrons escape. Each neutron from the source must therefore appear as a thermal neutron somewhere in the tank. By integrating the thermal-neutron density—measured by its effect on a foil calibrated in a known thermal-neutron density—the neutron emission rate of the source is obtained.

The second type of absolute measurement of neutron source



Drawing of the standard thermal neutron flux geometry used at the U.S. National Bureau of Standards to calibrate the fluxes of unknown sources

strength involves activating a water bath containing manganese sulphate. Neutrons from the source are slowed down in the bath and are captured finally either by manganese atoms or hydrogen atoms. The number of manganese atoms activated is measured by a method which amounts to absolute counting of the induced beta-ray activity of the manganese. The fraction of neutrons lost to hydrogen is estimated either from the measured manganese and hydrogen thermal-neutron absorption probabilities (cross-sections) or by changing the concentration of manganese in the bath and comparing activations.

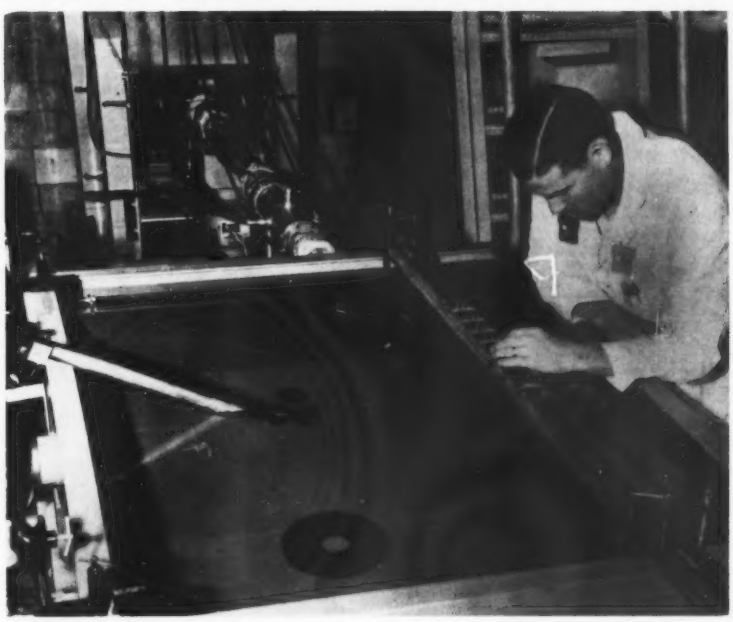
Standard Arrangement

The standard thermal-neutron flux geometry used for calibrating neutron fluxes consist of two symmetrically placed radium alpha-beryllium sources surrounded by lead and paraffin with a carbon-shielded detector slot in between. The neutrons are slowed down by the shielding materials before reaching the slot. The thermal-neutron flux in this slot has been calibrated by absolute counting of the boron-10 (n, α) reaction, the thermal-neutron cross section for this reaction being well known. From observations of the count rate in a proportional counter or pulse ionization chamber containing a known amount of B10, the thermal-neutron flux can be determined. The standard thermal-neutron flux of the U.S. National Bureau of Standards is known to within about 2 per cent. Investigations are presently under way aimed at an independent calibration of this flux by beta-gamma coincidence counting of gold-198. Unknown fluxes are calibrated against the standard by activating foils in both.

The detection of neutrons in the presence of gamma rays, or of gamma rays in the presence of neutrons, is often a difficult problem. The most satisfactory method for analysing such mixed radiation employs a pair of detectors, one sensitive to neutrons only, and the other sensitive to gamma rays only. Mixed-radiation dosimetry, however, is even more difficult because detectors in order to read dose must have a specific dependence upon neutron or gamma-ray energy. Instruments for neutron dosimetry may be designed to respond in two ways. The first way, which is most important for measuring the relatively hazardous fast neutrons, is to make the response of the instrument proportional to energy absorbed/gm in soft tissue. Such an instrument may be calibrated in rads for tissue, where one rad is 100 ergs/gm. Other neutron radiation instruments have a response which is inversely proportional to maximum permissible neutron fluxes. The reading of such an instrument gives a direct indication of radiation hazard, valid for all neutron energies up to 20 MeV.

"Button" Detectors

Fast-neutron detectors consisting of zinc-sulphide grains dispersed in a hydrogeneous plastic "button" have been widely used because of their excellent gamma-ray discrimination. Recent work at the Bureau has demonstrated that many other kinds of phosphor material may be incorporated in "buttons," yielding simple, reliable detectors with good gamma ray discrimination. For example, plastic-phosphor matrix detectors using organic-plastic phosphors have a much faster response time than other neutron detectors which also provide good gamma-ray discrimination. By adding a material such as boron or lithium, which have large probabilities of undergoing an (n, α) reaction, to a button detector, it may be possible to develop a simple neutron survey meter with proper energy response for dosimetry from 20 MeV down. Other advantages provided by the use of inorganic phosphors, such as potassium iodide and sodium iodide, are greater button transparency and higher efficiency. Development of fast-neutron survey meters based on this generalized



Experimental arrangement for determining neutron penetration in water at the U.S. National Bureau of Standards

plastic-phosphor matrix principle is planned by the U.S. Navy Bureau of Ships.

Photographic film is widely used as a gamma ray dosimeter in mixed neutron and gamma ray fields. Although this film has a low neutron sensitivity, the extent of its neutron response must be accurately known for the correct interpretation of experiments such as radiobiological studies. A very pure neutron field must therefore be produced so that gamma radiation will not be present to mask the effects of the neutrons. To provide such a field, neutrons from the H^2 (d, n) He^3 reaction (often called the d+d reaction) are used, which are initially free of gamma radiation. Inelastic scattering, which is responsible for gamma ray production, is largely eliminated by the use of a specially constructed lightweight aluminium target assembly with a Van de Graaf accelerator.

Gamma Ray Dosimeter

To measure the small gamma ray contamination of the radiation field, a neutron-insensitive gamma ray dosimeter was developed. This instrument is a helium-CO_2 gas-filled counter with graphite-lined aluminium walls. Heavy-particle recoils caused by neutrons produce large pulses, which are discarded in the electronic data recording system. Small pulses, produced by secondary electrons ejected from the walls or gas, represent true gamma ray sensitivity. Radiation fields in which the fast neutron dose is at least 100 times the measured gamma ray dose have been measured with this arrangement.

The programme of studies on neutron penetration and diffusion was instituted in 1952, when large discrepancies were noted between theoretical calculations of neutron penetration and experimental measurements. A 20 per cent. difference between experimental measurements of fission-neutron age in water and calculations of the same quantity caused a great deal of concern. By the use of neutrons which are nearly mono-energetic and whose energies are well known from classical mechanics, an independent critical check of slowing-down theory was conducted by the Bureau for the U.S. Atomic Energy Commission. Complementary calculations of neutron penetration and diffusion are now being carried out in the Bureau's radiation theory section.

Water Shielding

The experiments conducted used neutrons from the target of a 2 MeV Van de Graaf accelerator produced by the H^2 (d, n) He^3 and the H^3 (d, n) He^4 (or d+t) reaction. The measurements were usually carried out with water as the shield because of experimental convenience and uniformity, and the completeness of theoretical data for this substance.

In this work, three kinds of detectors have been used: thermal neutron detectors, such as indium foils and boron counters; indium resonance neutron detectors, which are indium foils enclosed in cadmium to shield out thermal neutrons; and a polyethylene-lined ethylene-gas-filled proportional counter which acts as a fast-neutron dosimeter with a response very nearly proportional to that of tissue. The measurements with thermal-neutron detectors and indium-resonance neutron detectors are of particular interest to the reactor designer who needs to know how far fission neutrons from the reactor fuel elements travel while slowing down to energies where they may be captured by uranium and produce fission in the next fuel element.

Theory Checked

The age (1/6 of the mean square crow-flight distance for neutron slowing-down) has been measured for 14.1 MeV neutrons from the H^3 (d, n) He^4 reaction and for 2 MeV to 3 MeV neutrons from the H^2 (d, n) He^3 reaction. The latter experiment is a more interesting check on theory, as the neutron cross sections used in the theoretical calculations are well known and the source of neutron energies lies near the average of the neutron energies for a fission-neutron source. A recent calculation is in excellent agreement with the H^2 (d, n) He^3 neutron measurement made by the Bureau.

A fast neutron dose measurement has been made with the very penetrating radiation from a 14.1 MeV neutron source. Besides providing data basic to nuclear reactor shielding theories, the results of this kind of experiment are directly applicable to shielding design for controlled thermonuclear devices.

Although further experimental checks of neutron penetration calculations are necessary and desirable, the present state of agreement between experiments and calculations is generally satisfactory. Perhaps the most useful experimental information that can now be provided for penetration calculations is neutron cross-section data. Although total neutron cross-sections are widely known for most elements, very little information is available on differential neutron cross-sections and angular distributions. Therefore, the programme will be directed more and more towards the measurement of these fundamental neutron cross-sections.

One of the methods used by the U.S. National Bureau of Standards to compare neutron standards. The cadmium wrapped pile of graphite (at right) is used to slow down the neutrons emitted by the source placed in a pile. The thermal-neutron density is then measured by counting neutrons with a boron-lined counter or by activating and beta-counting indium foils. Such a foil is shown above being placed in a cut in the graphite pile

Time-of-Flight Tests

Time-of-flight equipment suitable for these measurements is now being prepared. This equipment measures neutron energies by observing the flight time for a neutron to travel a given distance. Times are measured with a resolution of about 2 musec (2×10^{-9} sec.). Neutrons are detected in plastic scintillators followed by 14-stage photomultipliers. The short time interval is converted to a pulse height and recorded in a 256-channel pulse-height analyser. These experiments will be performed with the Van de Graaf accelerator in a low scatter building which has been recently constructed for this purpose.

"Radioactive Express"

SCIENTISTS at the U.S. Atomic Energy Commission's "Hanford Atomic Products Operation," directed by GEC, play with electric toy trains every day. The play is deadly serious. The GEC designed at Hanford a chemical laboratory for the analysis of extremely radioactive material. Study indicated that a miniature railway offered the best bet for remote manipulation of the dangerously "hot" liquids involved. The design called for a long, low, totally enclosed, 1 ft thick steel structure with lead glass windows and interior periscopes. Over 250 ft of model-gauge track, with dozens of loops and sidings, would rest on the floor of this "cave." At each siding a tiny elevator would be suspended over the track. When a little locomotive and flat car bearing radioactive liquid in a beaker pulled to a stop under an elevator, the unit would lower chemical equipment into the solution and one step in the analysis would be performed. A laboratory technician would have acted as "yardmaster," watching the switching and manipulating steps from outside the shielded "cave." Reliability of train operation was to be vastly increased by gearing down the locomotives to very low speed and by complete re-design of rolling stock to lower their centres of gravity. This contemplated model railway, with electronic controls and associated equipment, would have cost over $20,000. The elevator and other specialized accessories were designed, and the mechanized analysis system was tested. Before design was fully completed, however, a change arose which made the whole chemical analysis not entirely necessary. But the design work served a pioneering purpose. The idea of using tiny remote control electric trains for transporting radioactive material from process station to process station still remains feasible, and is now being used for other radioactive "shielding" jobs at Hanford. The toy locomotives still carry "Top Secret" freight.

This building has thin metal walls and a grating floor to ensure that the neutrons observed in experiments originate from the sources and the neutron scatter and not from the walls of the room.

Future Work

The neutron, because of its lack of electrical charge, is a particularly interesting particle for investigating the nucleus. Among experimental measurements to be emphasized in the future, therefore, are determinations of angular distributions of neutrons scattered by nuclei and measurements of elastic and inelastic neutron scattering. This work is in line with the present shift of emphasis toward the provision of fundamental neutron interaction data.

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RADIATION and AGRICULTURE

(*Continued from page 488*)

Virginia, U.S.A., where biochemicals are produced from animals and plants reared on enriched environment, such as in the case of an atmosphere of $C^{14}O_2$. Closed-cycle feeding is used, in gas-tight laboratories. Theoretically, it should be possible to feed animals on radioactive materials, and then to use the excreta to fertilize plants, which will then biosynthesise radioactive compounds. The various practical difficulties in this idea have not yet been satisfactorily solved. Nevertheless, from the cultivation of plants such as buckwheat, foxglove, lucerne, poppy, rye, soya, and tobacco, radioactive materials such as digitoxin, morphine, nicotine, and other alkaloids, as well as sugars, proteins, amino acids, and vitamins have been produced. These have been used not only in tracer research work, but also for clinical medicine.

(*To be continued*)

The Sodium Reactor Experiment operated by Atomics International in the Santa Susana Mountains, near Los Angeles, California.

SUPERHEAT from S.R.E.

NUCLEAR superheated steam of 1,000°F. has been generated by heat from the Sodium Reactor Experiment (SRE), marking the highest steam temperature ever produced by heat from an atomic reactor. The SRE, located in the Santa Susana Mountains near Los Angeles, California, is an experimental nuclear power development project conducted by Atomics International for the U.S. Atomic Energy Commission. The power reactor has been operating for two years and has provided heat for the production of 15,355,000 kW hours of electricity by the Southern California Edison Co.'s steam generating plant adjacent to the reactor.

Molten sodium, the heat transfer medium, reached a temperature of 1,060°F. during the record power run. Sodium carries heat from the reactor core to the steam generating plant.

Data from the high temperature operation has provided additional experience on the technical feasibility of the sodium-cooled, graphite-moderated concept of economical atomic power.

Technical information gained from the SRE is being utilized in the design of the central station nuclear power plant being built by Atomics International for the Atomic Energy Commission at Hallam, Nebraska. Consumers Public Power District of Nebraska will operate the plant, which will use a Sodium Graphite Reactor as the heat source for the generation of 75,000 kW of electricity.

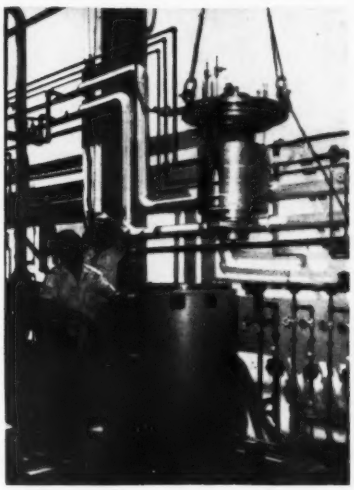
Experience gained with the SRE has shown the reactor to have a fast response negative temperature coefficient and a negative power coefficient. The resultant stability of the reactor is noteworthy.

During a recent power run, integrating timers on the automatic control system showed the rods were in motion only 3.5 min in 144 hr to maintain steady state full-power operation. The reactor can be completely shut down and restarted as fast as the control rods can be driven in and out, 20 min each direction. The ability of the reactor to follow load demand has been demonstrated by changing the reactor power at the rate of 20 per cent./min, or a 50 per cent. power change in 2½ min. More detailed studies indicate that even this high rate of change can be increased markedly.

Extensive physics experiments using both the "classical" and the oscillator techniques have established the accuracy of the methods used

to calculate the reactor parameters. Power oscillator tests have permitted establishment of nuclear parameters such as control rod calibrations, temperature coefficients and power coefficients to very close tolerances. The latter technique promises to offer considerable saving of time in the initial start-up of new nuclear power plants.

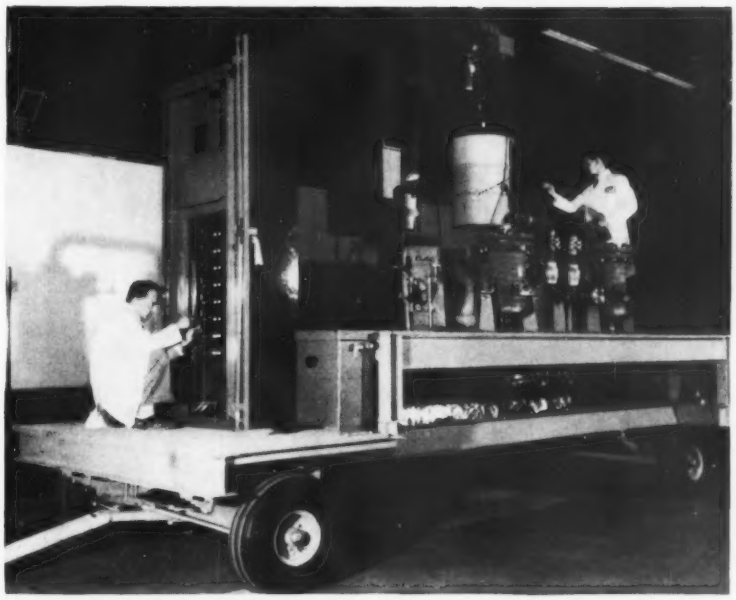
Through fuel transfers, experiments, maintenance and modifications, requiring penetration into sodium containment vessels, oxide from any air which entered has been readily removed by cold traps and hot traps. In the initial sodium filling of the reactor systems, only 20 parts/million of oxides were measured in the sodium prior to any effort to remove them. During reactor operation, the oxides in the primary sodium system can be maintained well below 10 parts/million by continuous operation of the hot traps. The tightness of the piping and vessel system is evidenced by the fact that the oxide concentration of the sodium remained below 5 parts/million during a one week period in which neither the hot trap nor the cold trap was operating.



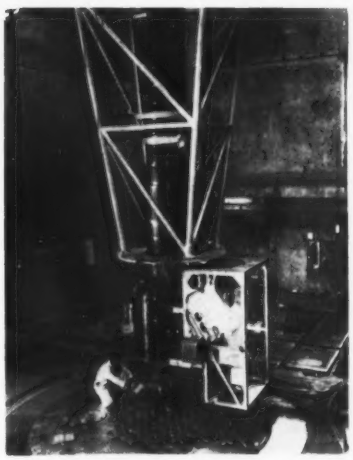
The main secondary liquid sodium pump for the SRE

In addition to power generation, maximum utilization of the reactor has been made in experimental work to establish and promote the technology of this reactor concept. One of the primary experiments has been with reactor fuel materials and fuel geometries. These tests are being conducted on many types of fuels simultaneously. One of the fuel elements recently examined which had a power history of 600 MWD/T average and 1,000 MWD/T at the maximum region of the element had suffered no dimensional changes in the rods.

During the experimental fuels programme more than 1,000 core element transfers have been effected without incident with the fuel handling cask and have at all times maintained an inert atmosphere in the cask and in the reactor when their atmospheres were mutually connected.



In connection with their studies of sodium reactor systems, Atomics International have developed a portable melting unit, which eliminates the need for every sodium cooled reactor plant having its own melting facilities. In the portable unit there are two 55 gal heaters in which the sodium is liquefied. From these it is gravity fed into a foil insulated tank beneath the platform. From there it is forced under pressure into two filter tanks before being transferred into the reactor. The illustration shows technicians preparing a barrel of sodium for the melting operation



Fuel loading-unloading apparatus on face of the SRE

It is of interest that the use of sodium as a coolant permits selection from among a wide variety of fuel element materials, since sodium is compatible with most metals. Also, since sodium has a low vapour pressure at the temperatures achieved in modern steam plants, a costly pressure vessel and thick-walled piping are not required in the construction of the plant.

An irradiated fuel element being removed from the SRE, as seen over the closed circuit television

Power from a "fruit can"

DIRECT CONVERSION OF REACTOR ENERGY

THE Los Alamos Scientific Laboratory, operated by the University of California for the U.S. Atomic Energy Commission, has recently developed a new device by means of which the first direct conversion of nuclear reactor energy into electric power has been made possible.

The important achievement was the result of an experiment with the laboratory-developed "plasma thermocouple" placed in the core of a heterogeneous research reactor. Modestly calculated to produce enough power to light an electric bulb for a few minutes, the lifetime of the device far exceeded all expectations. Acting like a super-powered flashlight battery—with an open circuit voltage of 3.8v and a short circuit current between 30 and 40 amperes—the thermocouple was operated at design efficiency for almost 12 hr before it was shut down and dismantled for analysis.

Far-reaching Implications

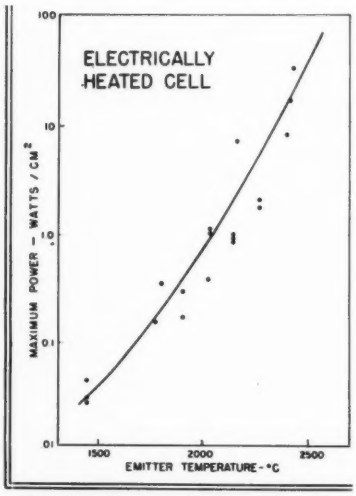
When this single cell is extrapolated to an entire reactor, the implications of a successful plasma thermocouple to future atomic energy developments are great and far reaching. Requirements of present fission reactors are that they produce high pressure steam to power huge turbines which in turn make the conversion to electricity. In bypassing this intermediate step, along with its drawbacks of excessive weight, bulk and complexity, *the new thermocouple opens up new vistas in the fields of nuclear propulsion in both submarine and space travel.*

Development of the new plasma thermocouple was a three-year, laboratory-wide accomplishment, with scientists from the nuclear rocket propulsion research division spearheading the work. The men were group leader George Grover, Duane Roehling and Ernest Salmi, all of the laboratory staff, and R. W. Pidd, a consultant from the University of Michigan.

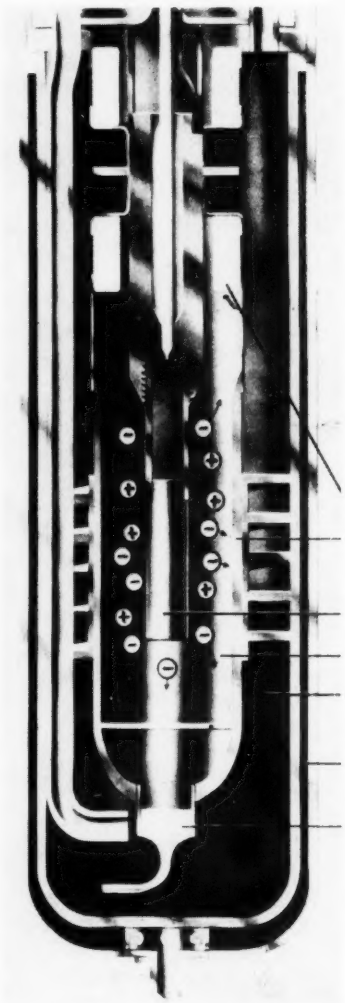
What is a thermocouple? Basically, it is a well-known means of producing electricity by bringing two different metals into contact, then cooling one metal and heating the other. The Los Alamos thermocouple is the result of a laboratory observation, made recently, that substituting ionized caesium gas (plasma) for one of the metallic elements produced direct current at several hundred times the power of earlier thermocouples.

The experimental plasma thermocouple resembles in size and shape an empty frozen fruit juice can. The source of power is a rod about $\frac{1}{4}$ in. in diameter and $\frac{3}{4}$ in. long containing enriched uranium. This is suspended in the centre of the cell and surrounded by caesium gas. When the assembly is lowered into the core of a reactor, the neutron flux activates uranium fission heating in the centre of the can, while the flow of reactor coolant around the outside of the can drops the temperature of the caesium plasma. The essential requirements of a thermocouple thus are met, and electricity is produced.

In pointing out the advantage of a plasma thermocouple reactor over a reactor-plus-electric turbines, Los Alamos scientists stress its simplicity (no moving parts), potential efficiency, extreme low weight, and small cost.



Graph showing the relation between the power used and the heat achieved in the process of conversion in the plasma thermocouple developed by Los Alamos scientists



Cutaway diagram (twice actual size) of thermocouple used by the Los Alamos scientists to produce electricity direct from fission power

N-Energy at former aircraft centre

RESEARCH AT SLOUGH

DURING the few years it has been in existence the Hawker Siddeley Nuclear Power Co., has established a firm foothold in Britain's nuclear engineering industry. Among the company's achievements so far are the design and development of a low power research reactor, JASON, the prototype of which is now under construction, and the design of an organic moderated power reactor plant for marine propulsion. This is one of the systems being considered by the Admiralty for possible use in Britain's first nuclear propelled commercial ship. In addition, the company is carrying out many research projects and studies, not only for its own ultimate application but also for the United Kingdom Atomic Energy Authority and overseas industrial organizations.

Impressive Background

The company was formed in 1955 by the Hawker Siddeley Group, for the main purpose of designing and developing small capacity reactor plants, principally for industrial and propulsion applications. The Hawker Siddeley Group is a powerful association of well over 70 companies, among them being the Hawker Aircraft Ltd., Brush Group Ltd., Dominion Iron and Steel Ltd., Petters Ltd., Sir W. G. Armstrong Whitworth Aircraft Ltd., and A. V. Roe & Co., Ltd. It was only natural that a group with such connections should enter the new and exciting field of nuclear engineering.

Over 250 Staff

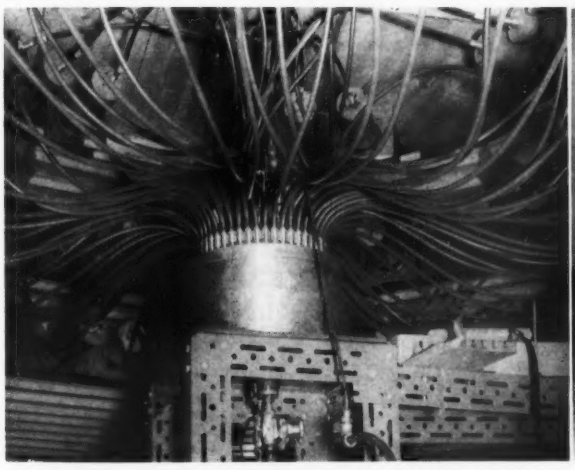
Headquarters of the Hawker Siddeley Nuclear Power Co., are at Langley, Slough, about 20 miles west of London. There they occupy large, well equipped laboratories for the tackling of all manner of metallurgical, chemical and engineering problems. The staff of scientists, engineers and technicians number 260.

JASON, the Hawker Siddeley research reactor is a 10 kW water cooled water moderated unit based on the design of the American designed ARGONAUT. Fuel is 20 per cent. enriched uranium. With the reactor it will be possible to carry out many nuclear physics and chemistry research experiments, produce isotopes and provide scientists and engineers with reactor operation training. It is hoped to sell the reactor to universities, hospitals and industrial concerns interested in keeping abreast of nuclear technology. Versions of the reactor in varying degrees of simplification will be available, thus enabling the owner to build up, in stages, a reactor with maximum operational facilities.

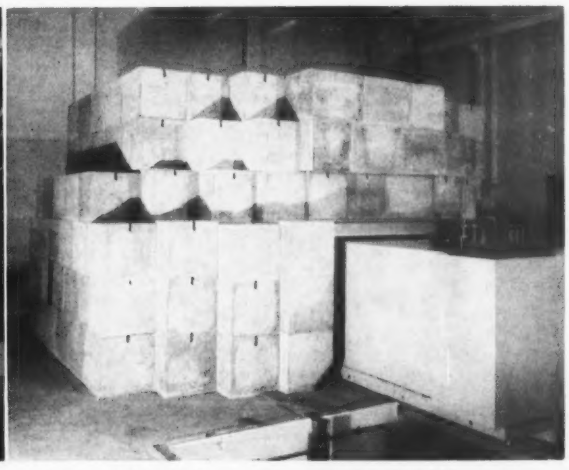
The prototype has been built at Langley in a hangar that was once the home of famous Hawker Hurricane aircraft. It will be used not only as a demonstration model to potential purchasers but also as a research tool for Hawker Siddeley.

It is of interest to mention here that before the company made known its intention of building a reactor at Langley it invited members of the local town council to visit the site and hear an explanation of the safe operation and maintenance of a reactor. So impressed were the local councillors that they accepted the company's proposal without demur—there was not the fuss and bother that has attended the announcement of reactor proposals elsewhere, due mainly to the company's intelligent approach to the matter.

Among the first tasks allotted to JASON will be the investigation of theoretical calculations for the



A 2m. ampere discharge can be handled by this high current switch developed by Hawker Siddeley for the AERE, Harwell. It has been produced for controlled thermonuclear reaction projects



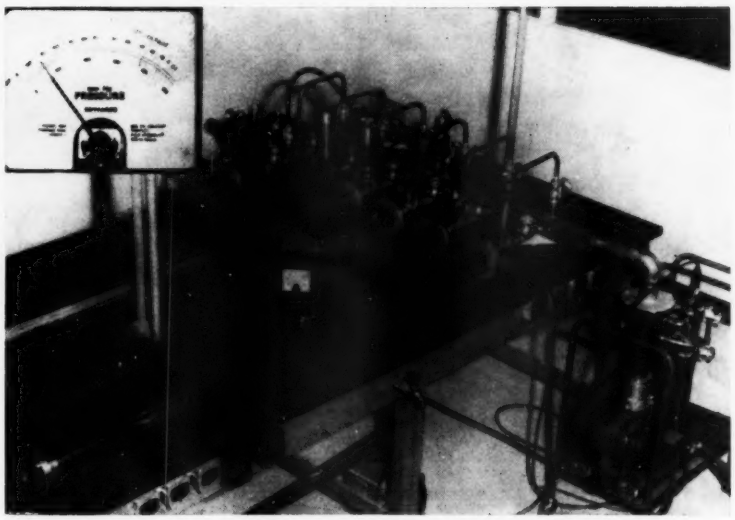
View of the prototype Hawker Siddeley JASON reactor shortly before being tested. The reactor, of the thermal heterogeneous type, is designed for research, training and industrial uses

company's organic moderated reactor system for marine propulsion. The company has full confidence in this system and even if it is not chosen by the Admiralty for their first marine project it could well be selected for the second project. With JASON, Hawker Siddeley will be able to confirm many of their calculations and so add weight to the case they have built up for its acceptance as a safe, economical and extremely practical unit.

Practice Backs Theory

Even now all this is not based on theory. Practical work has for instance, been carried out on terphenyl, the coolant to be used in such a system. Many physical and chemical tests have taken place to determine its suitability in a reactor system, some of the experiments having been of spectacular nature.

In addition to the organic moderated system the company has worked on the liquid metal fuelled system and on fused salts which might be used in or associated with reactors. The LMFR uses bismuth as coolant and Hawker Siddeley have carried out extensive investigations into the chemical and physical properties of this metal and research into the development of ways of overcoming the problems involved in its use. Much of this work was at one time undertaken under contract to the U.K. Atomic Energy Authority; the Authority, however, has since dropped its interest in the system and the work is now done for the benefit of the company and its clients.

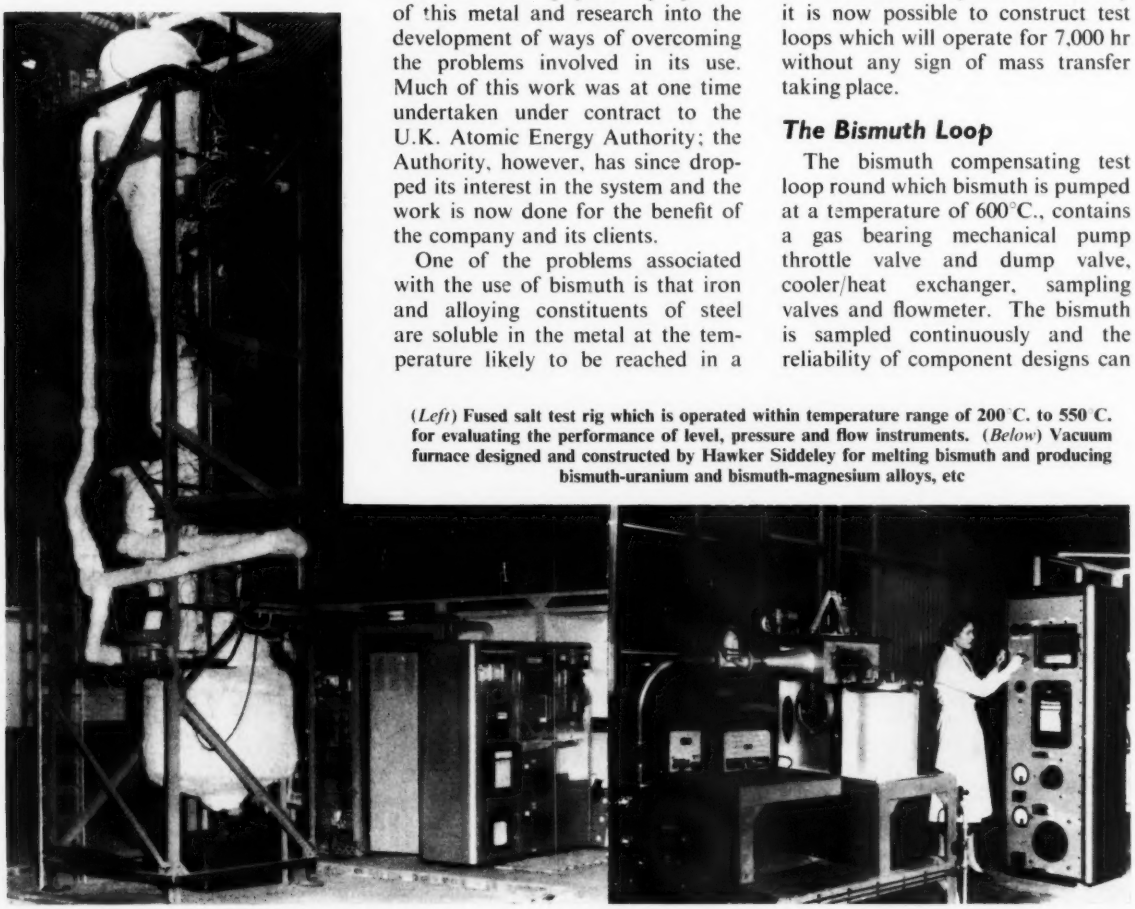


Testing the permeability of impregnated graphite specimens, including fuel elements for the HTGCR

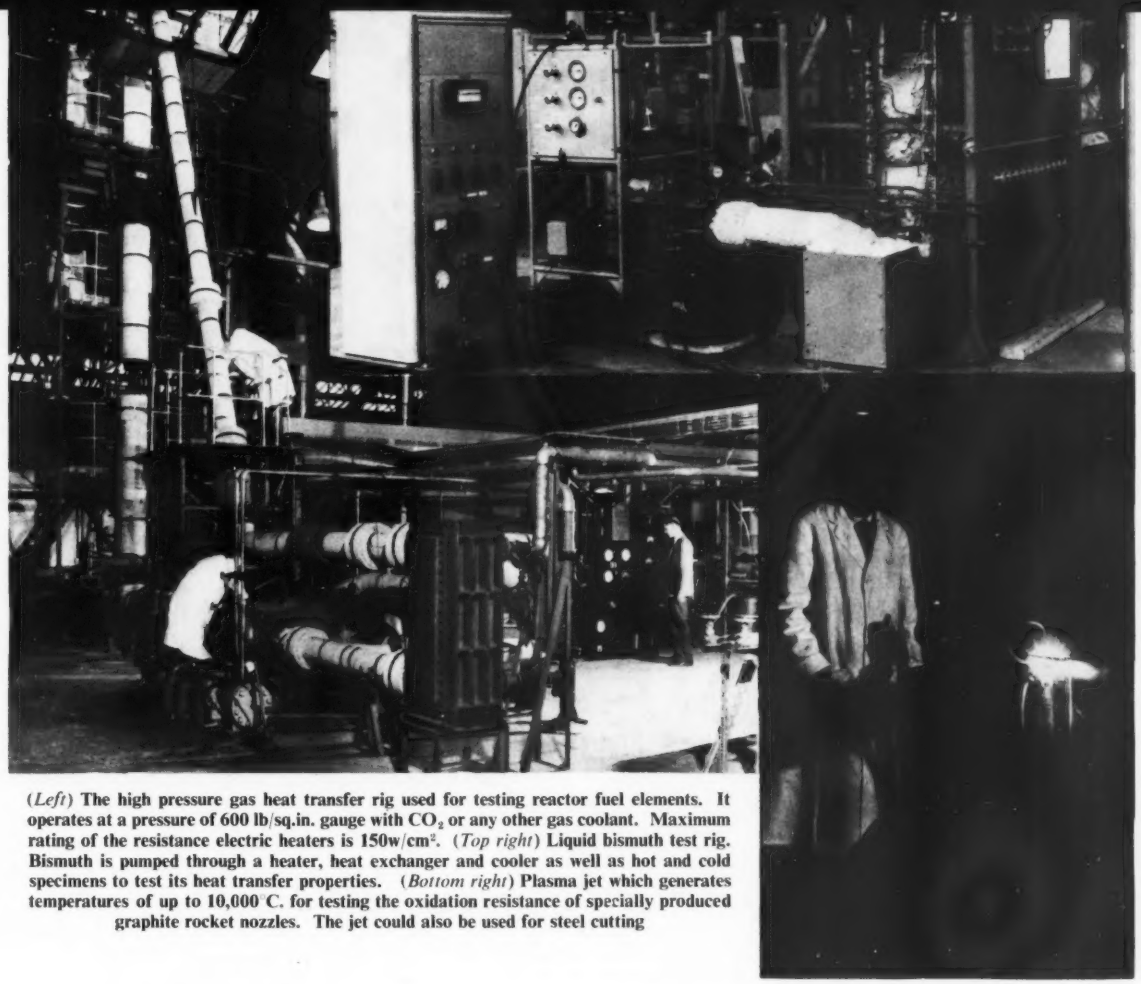
One of the problems associated with the use of bismuth is that iron and alloying constituents of steel are soluble in the metal at the temperature likely to be reached in a reactor. To overcome this, either the steel can be specially pre-treated or certain "inhibitors" introduced into the bismuth. With the information accumulated by Hawker Siddeley it is now possible to construct test loops which will operate for 7,000 hr without any sign of mass transfer taking place.

The Bismuth Loop

The bismuth compensating test loop round which bismuth is pumped at a temperature of 600°C., contains a gas bearing mechanical pump throttle valve and dump valve, cooler/heat exchanger, sampling valves and flowmeter. The bismuth is sampled continuously and the reliability of component designs can



(*Left*) Fused salt test rig which is operated within temperature range of 200°C. to 550°C. for evaluating the performance of level, pressure and flow instruments. (*Below*) Vacuum furnace designed and constructed by Hawker Siddeley for melting bismuth and producing bismuth-uranium and bismuth-magnesium alloys, etc



(*Left*) **The high pressure gas heat transfer rig used for testing reactor fuel elements. It operates at a pressure of 600 lb/sq.in. gauge with CO_2 or any other gas coolant. Maximum rating of the resistance electric heaters is 150w/cm². (*Top right*) Liquid bismuth test rig. Bismuth is pumped through a heater, heat exchanger and cooler as well as hot and cold specimens to test its heat transfer properties. (*Bottom right*) Plasma jet which generates temperatures of up to 10,000°C. for testing the oxidation resistance of specially produced graphite rocket nozzles. The jet could also be used for steel cutting**

be tested by long-term high temperature continuous operation.

Facilities are provided for the investigation of other elements. Typical of the work are the determination of solubility rates and mass transfer characteristics of steel in liquid metals, the reduction of mass transfer by the development of surface treatments for constructional materials, investigation of the corrosion of aluminium and alloys in water, and the examination of the resistance of steel and of non-metals to attack by molten salts.

Creep Testing

The creep and stress rupture properties of materials in liquid metal environments have been determined in specially devised equipment, which permit the work to proceed in either inert or controlled atmospheres. Further studies are being made on the high temperature oxidation characteristics of high temperature materials and on the development of graphite with a high degree of impermeability.

The impregnation process has been developed in association with the Royal Aircraft Establishment, Farnborough, and was initially worked under contract to the UKAEA for the production of fuel cans.

Outside N-Field

This graphite has, however, many applications outside the nuclear field, due to its impermeability being retained up to at least 2,000°C. and to its improved physical and mechanical properties. Orders have been received by the company for the impregnation of melting and casting crucibles, bursting discs, face seals and rocket nozzles etc. The material can be made with a wide range of permeabilities as well as various carbide coatings to the customers choice. Ionization chambers have also been produced.

For the alloying and purification of liquid metals a special melting and charging unit is available. This installation deals with charges of 56 lb of melt and operates in a vacuum or an inert gas at a temperature of up to 700°C. An ultimate pressure of .003 mm Hg can be achieved with a leak rate not exceeding 0.01 mm Hg/hr without pumping. The unit is so designed that without interrupting the process, alloying additions can be made and samples taken for analysis. At the same time the melt can be continuously stirred, hydrogen passed through it to reduce impurities and the content finally poured into containers for further experimental work or into ingot moulds.

A major piece of equipment at Langley is a fuel element heat transfer test rig, which enables tests to be carried out in conditions closely approaching those of an actual reactor.

Constructed at a cost of about £60,000, the installation includes a high pressure gas cooled closed circuit in which a maximum pressure of 600 lb/sq.in. area (40 atm), maximum channel rating of 750 kW, and a maximum channel Reynolds Number of 7.5×10^5 in a $3\frac{1}{2}$ in. diameter channel can be obtained. The dimensions of the test channel are adjustable, the length between 7 ft and 20 ft and the diameter from

(*Continued on page 510*)

HYDROCARBONS IN POWER REACTORS

III—Application of OMR to central station power plants*

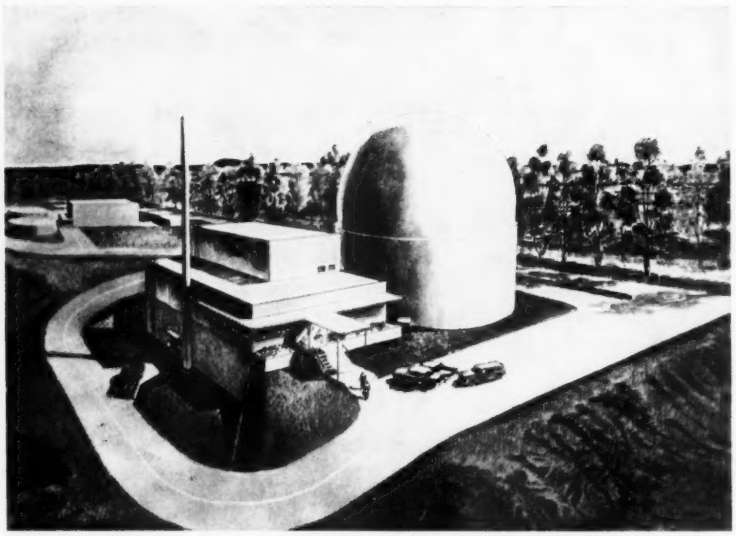


Fig. 1.—Artist's impression of the 45.5 MW (thermal) organic moderated reactor power plant to be built at Piqua, Ohio, by Atomics International

ONE of the most promising reactor types for power applications is based on the use of an organic material as moderator and coolant. Research on organic moderated and cooled reactors has been carried out for a number of years at Atomics International and at several other sites.

In response to the second invitation under the power Demonstration Reactor Programme by the United States Atomic Energy Commission, the City of Piqua, Ohio in 1956 proposed that an organic moderated and cooled reactor be built to supply steam for the generation of 12.5 MW (gross) of electricity in their municipal power plant. Atomics International are to build the reactor plant, which will be owned by the U.S. Atomic Energy Commission and operated by the City of Piqua.

An artist's impression of the exterior of the reactor plant is shown in Fig. 1. An idea of what an organic moderated and cooled power reactor plant might look like inside is given by Fig. 2.

The reactor, steam generators, primary coolant system components and associated auxiliaries will be located below ground level in concrete vaults, while the fuel handling system, control room, work areas and turbine generator will be at ground level. Conceptual drawings of possible layouts for these two floors are shown in Figs. 3 and 4. In the Piqua plant the reactor will serve existing turbo-generating equipment, so the turbo-generating areas shown in these drawings and Fig. 2 will be omitted.

**Paper presented at 2nd International Conference on the Peaceful Uses of Atomic Energy by E. F. Weisner and W. E. Parkins.*

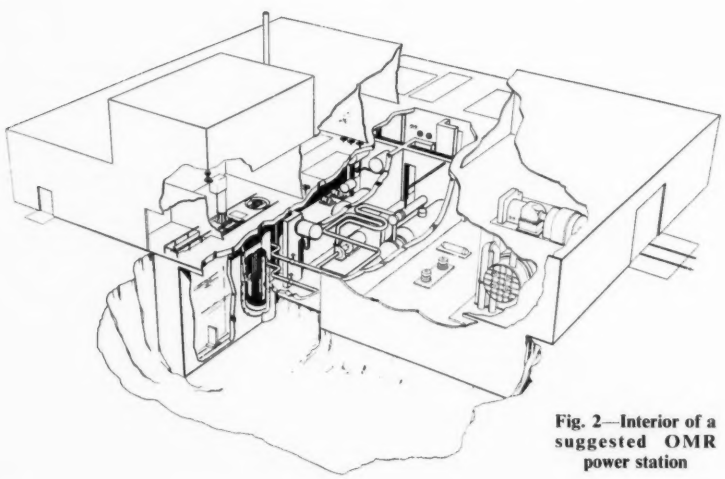


Fig. 2—Interior of a suggested OMR power station

Organic Flow

A simplified flow diagram for the Piqua reactor is shown in Fig. 5. The organic is circulated through the core and out into two external loops containing the pumps and heat exchangers. The heat carried by the organic is given up directly in steam generators and superheaters to produce steam to drive the turbine. The gas content of the organic is controlled by passing a side stream of coolant through a low pressure degasifier tank. The return fluid from this tank is fed to the main stream by a pump which maintains the proper pressure on the primary system. During operation, the main reactor tank is completely filled with organic. The heavy polymers produced by radiation in the core are removed in a still, and the undamaged organic returned to the main stream together with the necessary amount of new make-up material.

The organic system uses low carbon steel throughout for all piping and components. This is an inherent

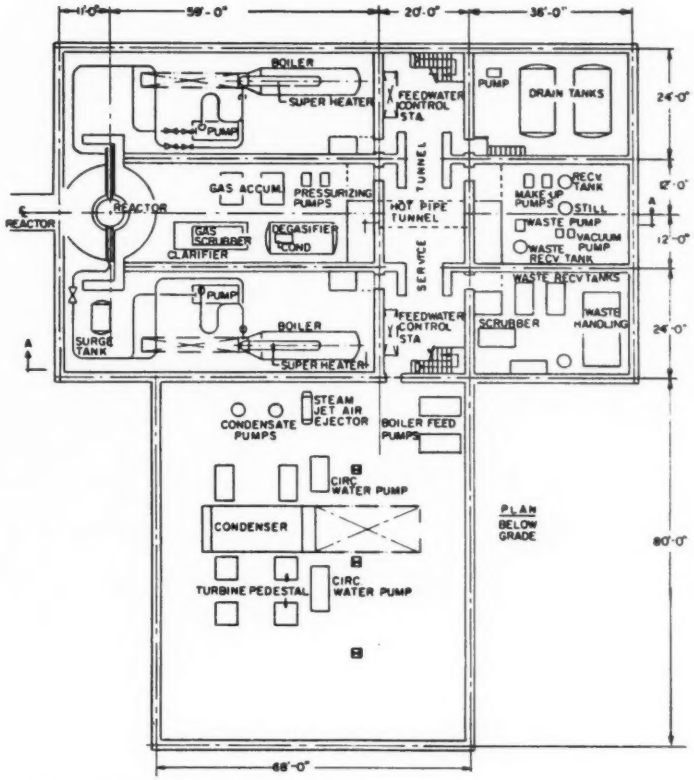


Fig. 3—Basement plan of suggested OMR power station

advantage resulting from using organic fluids since they exhibit negligible corrosion of ordinary materials of construction such as aluminium, stainless steels and low carbon steels. The corrosion rate of uranium in organic is also quite low.

A sectional view of the reactor core is shown in Fig. 6. The fuel elements are positioned between the upper and lower grid plates. Control-safety rods are arranged among the fuel elements and are completely contained within the core vessel; only the electrical leads needed for their operation penetrate the core tank.

Coolant in Core

The core is surrounded by an inner thermal shield, the core tank and an outer thermal shield. The organic coolant is pumped into the region above the core, flows downward through the fuel elements into the lower plenum, upward through the annulus between the core tank and inner thermal shield, and out to the steam generators. The reactor foundations are designed to provide the required biological shielding in addition to supporting the core vessel and top shield. The core tank has a bolted cover, using a soft metal gasket seal such as copper, iron or aluminium.

Plate Type Fuel

The type of fuel element planned to be used is shown in Fig. 7. Several fuel element types were studied, including pin type and parallel plate types with and without fins. On the basis of relative heat transfer, coolant pumping power, amount of cladding material required, and estimated cost of manufacture, the parallel-finned-plate type, single pass was selected for development.

The fuel elements are about 5 in. square and are positioned on a 6 in. lattice pitch. The active length of the element is 4 ft 6 in. Aluminium extrusions of this type have been obtained and used in fuel plate cladding experiments. These extrusions have extended surface fins on their outer sides and a hollow core into which nickel-plated uranium alloy fuel is inserted. The aluminium and the plated fuel are then metallurgically bonded by hot pressing.

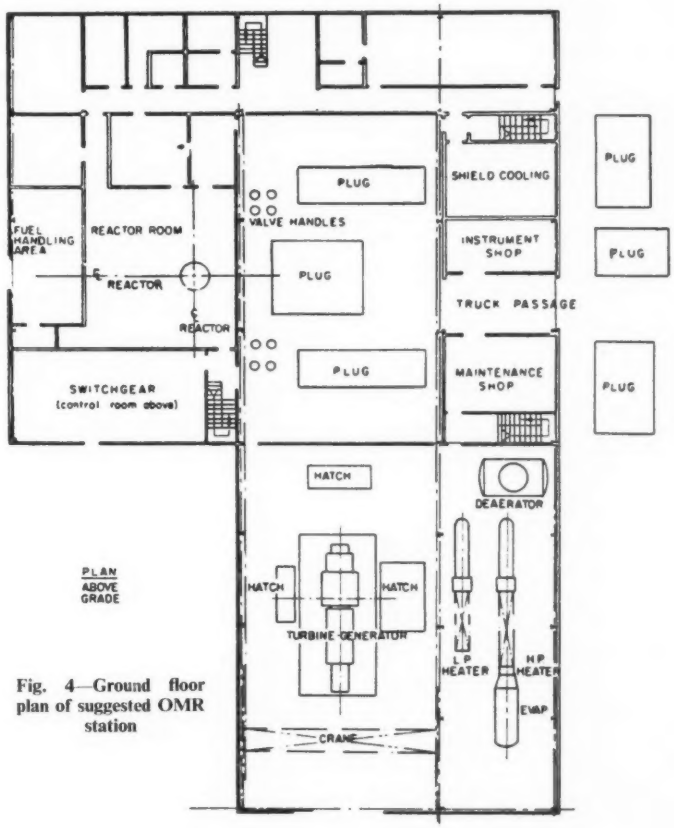


Fig. 4—Ground floor plan of suggested OMR station

Test elements using this design are now being manufactured with dimensions such that they can be inserted in the OMRE for irradiation testing.

Control is effected by seven boron rods. The poison element, its drive, position indicator, and snubber are arranged in a compact, unitized assembly which is entirely contained inside the reactor tank and immersed in the coolant above the core. The control element assembly is designed so that it can be inserted in a standard fuel element opening in the core. The maximum diameter of the drive above the core is limited to 6.25 in. and therefore does not interfere with refuelling operations. Electrical leads for the rod drive and position indicator are brought into the reactor tank by a nozzle near its top and are connected to the rod by means of cable quick-disconnects.

The drive selected for the unitized concept is the magnetic jack which is similar to the type that has been under development at Argonne National Laboratory for about the last five years. All major components of the control-safety rod are presently under test. A full size prototype rod assembly is now being manufactured and will be tested in an experiment duplicating reactor operating conditions.

Fuel Handling

The fuel elements and control rod assemblies are inserted and removed by means of a fuel handling system similar in design and operation to that of the EBWR. Fuel elements are removed from the reactor core into the cask which is mounted on a carriage. The carriage travels on rails straddling the reactor top shield and is designed to position the cask over any one of the fuel element or control rod positions. Fuel elements are placed in or removed from the core by a latch assembly which is lowered into the core tank through ports in the top shield and core tank head.

During fuel removal operations, the core tank head is unbolted from the core tank flange and rotated with the top shield. The top shield is designed to control the escape of vapours from the core tank during fuel changing operations. When fuel elements are handled normally and without complication, no cooling is required in the cask; however, the cask is equipped so that the shielded compartment can be filled with water. This feature is a precaution to prevent overheating of the fuel element, if for some reason it has to be held in the cask for an extended period. The fuel handling system is also used to remove control rod assemblies from the reactor by a procedure similar to that used in removing a fuel element.

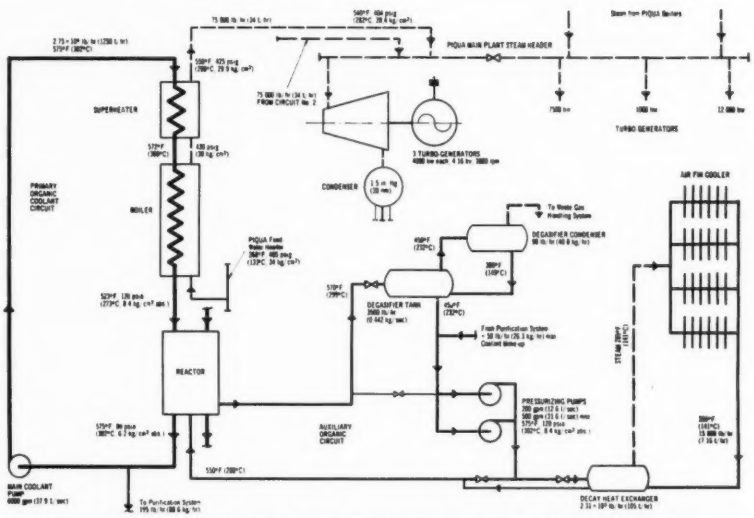


Fig. 5.—Simplified flow diagram for the Piqua reactor. (Drawing is reproduced with permission of the IAEA from " Directory of Nuclear Reactors ")

Design Parameters for Proposed Piqua OMR plant

General	
Net output	45.5 MW (t.)
Net station efficiency	25.1 per cent.
Fuel	1.8 per cent. enriched uranium
Reactor	
Core diameter	60 in.
Core height	54 in.
Number of fuel sites	85 (7 occupied by control rods)
Lattice pitch (hexagonal)	6 in.
Organic fluid charge in core	1,600 litres
Fuel charge in core	6,870 kg
Nuclear Data	
Burn-up	3,000 MWD/tonne U
Mean thermal neutron flux in fuel	1.4×10^{13} n/cm² sec
Fuel Elements	
Active length	54 in.
Active fuel cross section	3.8 in.²
Cladding thickness	0.030 in.
Max. cladding temperature	750°F.
Max. fuel temperature	880°F.
Coolant System	
Temperature core inlet	523°F.
,, core exit	575°F.
Pressure-core inlet	120 lb/sq.in. atm.
,, core exit	89 lb/sq.in. atm.
Total mass flow in system	$5.5. \times 10^6$ lb/hr
Max. coolant velocity in core	14.6 ft/sec
Control Rods	
Number	7
Active length	48 in.
Fabrication material	Boron or B_4C
Total worth	10 per cent. $\frac{\delta k}{k}$
Scram time	delay 0.07 sec
,,	travel 0.5 sec

Leakage Unlikely

Each of the primary loops contains a shell-and tube, horizontally mounted steam generator constructed of mild steel. Each steam generator consists of a boiler and a superheater designed to produce superheated steam at 450 lb/sq.in. atm. and 550°F. The superheater is a shell-and-tube counterflow heat exchanger while the boiler is a typical shell-and-tube re-boiler. The organic flows through the tubes in each case while the water or steam is on the shell side. Each exchanger is of the U-tube design with a double tube sheet. The space between the tube sheets is monitored for leaks of either organic or water. This type of design minimizes the chances of leakage between organic and water.

The pressure on the primary system is maintained at about 120 lb/

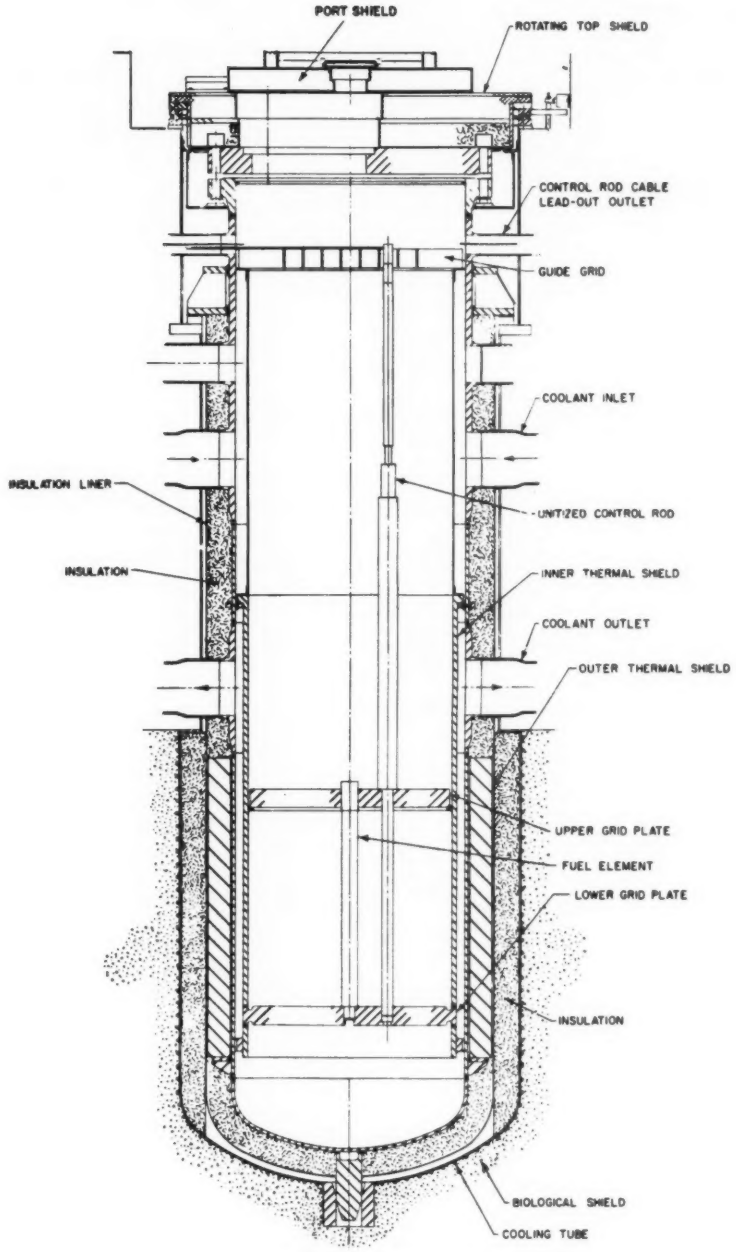


Fig. 6.—Section through the reactor designed for the Piqua station

sq.in. atm. by the pressure control valves located in the line to the degassing tank. An increase in system pressure causes an increase in flow rate to the degassing tank, while a decrease in pressure causes this flow to decrease. Coolant flowing into the degassing system is replaced in the primary loops by the continuous pumping of degassed organic back into the primary system. This is accomplished by the use of the centrifugal pressurizing pumps. Gas and vapour resulting from radiolytic decomposition of the coolant, from gases introduced in the coolant make-up, from small water or steam leaks, and from diffusion of pressurizing gas from the surge tank into the coolant are continuously removed by this degasifier system. The degassing tank also serves as the expansion tank for the primary system. The pressurizing-degassing system also serves as an emergency cooling system in case both primary loops should be inoperative.

A small amount of coolant is continuously bled from the primary loops to the purification system. It passes to a vacuum flash still where the lighter components of the coolant are flashed and the heavier components are carried downward. The heavier fractions are then fed to a distillation column where a final separation of the coolant and residues is effected. The light coolant vapours of the still are carried over into the condenser and returned to the degassing tank. The bottoms of the distillation column are piped to the residue storage tanks.

Purification Rate

The rate at which coolant should be fed to the purification system cannot yet be established. Studies at the OMRE will determine the rate of radiation damage to the coolant as a function of polymer content. If the damage rate is found to decrease with polymer content, the purification rate will be set to compromise between the low damage rate (low make-up) at higher polymer content and the better heat transfer properties characteristic of the lower polymer content.

The organic liquid presently planned for use in the Piqua reactor as moderator, coolant and reflector is Santowax R, a commercially available mixture of the three isomers of terphenyl. It is of the more stable

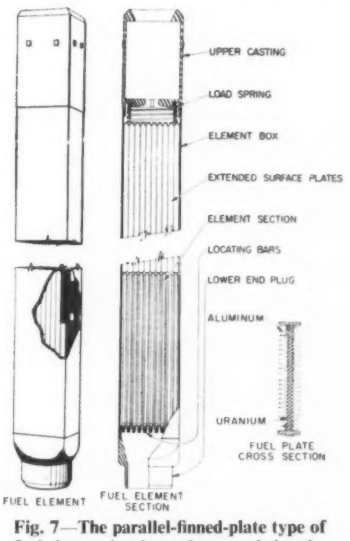


Fig. 7—The parallel-finned-plate type of fuel element has been chosen as being the most suitable for use in the Piqua reactor

organic liquids in regard to thermal and radiation decomposition at bulk temperatures in the neighbourhood of 600°F. The principal disadvantage of Santowax R is its fairly high melting range, 230°F. to around 300°F. This difficulty, however, can be overcome by proper design and operating procedures.

150 MW Units Feasible

Every effort has been made in the development of components for the 12.5 MW electrical organic reactor to develop components which could be used in multiple units for larger reactors. Some preliminary work has been completed on organic reactors producing up to 150 net electrical megawatts. The results indicate that the basic concept is applicable to any size central station power plant.

There are many features which make reactor plants of the OMR type both practicable and economical. Low system pressures can be used with the bulk coolant outlet temperatures of approximately 600°F. Corrosion is essentially absent and no hazard exists from possible chemical reactions within the core. Low cost materials of construction and standard field fabrication methods may be used. Induced radioactivity in the coolant is small, making for relatively easy system maintenance. Overall safety aspects of these organic moderated plants are excellent and demand little in the way of special containment features in the reactor housing. The enrichment of the uranium fuel of OMR plants ranges between 1.5 and 2.0 atomic per cent. U-235.

Piqua Economics

Atomics International's bid price for the Piqua reactor was $4,800,000 for plant construction and fabrication of fuel for five years' operation. This was a fixed price bid subject only to escalation, not to exceed 25 per cent. if upward, based on the cost of labour and construction materials. This price does not include turbo-generators and other auxiliary equipment which is being furnished by the City of Piqua. The capital charges for subsequent complete 11,400 kW (net) nuclear power plants are estimated to be approximately $500 per net installed kilowatt or $5,700,000 total. Treating the capital investment as an annual charge of 15 per cent. of the total investment, and assuming an 80 per cent. load factor, the capital investment contributes 9.5 mills/kWh to the total power cost.

Annual fuel costs depend to some extent on the fuel exposure time and on the load factor. In this reactor, the average exposure time is expected to be from 3,000 to 4,000 megawatt-days/ton; the load factor is estimated at from 60 per cent. to 80 per cent. depending on the application. Within these ranges, the fuel cost will be between 5.4 and 6.3 mills/kWh. This figure includes the burned fuel cost; fuel fabrication, processing, shipping, and inventory costs; and credit for plutonium.

Reductions Expected

At this stage of the OMR development programme, exact costs for plant maintenance are very difficult to predict. Based on information available, it is estimated that the fixed costs for operation, maintenance, and terphenyl make-up will total 2 to 3 mills/kWh.

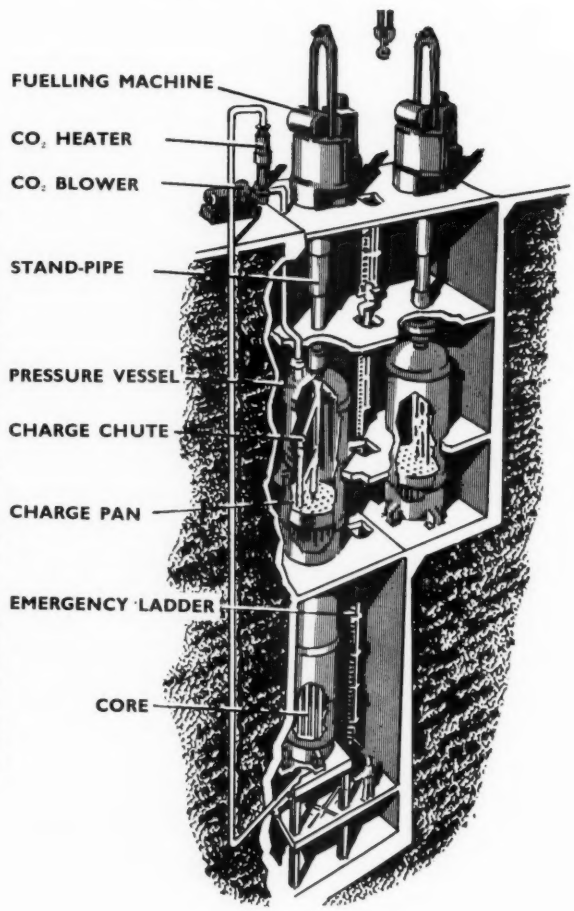
The total cost of power from this plant is thus about 18.5 mills/kWh. Although this figure is above costs from conventional plants in the United States, reductions are expected as advances are made in OMR technology.

Comparable figures for a 100 MW net electrical power plant are $280/net installed kW with a total power cost of approximately 10 or 11 mills/kWh.

There are definite indications that further developments in the field of organic technology and fuel elements, coupled with experience gained from the first plants, will lower the costs of the nuclear plants to where they will be actually competitive with conventional plants.

Fuel Charging Test Pit

In common with the other commercial nuclear power stations being built for the Central Electricity Generating Board, the 500 MW Hinkley Point station reactors will be refuelled whilst operating at full pressure and full load. To carry this out requires heavy, accurate, sensitive apparatus designed to overcome all the various problems involved. The fuel handling machinery for Hinkley Point is being built at the English Electric Atomic Power Centre, Whetstone, Leicestershire, and to test it a special 85 ft deep pit has been built in which the structure of a reactor charge face has been reproduced and in which the operating conditions of a reactor are simulated



CANNES, France

EXPERIMENTS are the scientist's spice of life, and as I write these lines on the sun-baked French Riviera, I still feel the exultation from my participation in a bold and important experiment. During the last two weeks of July, and under the auspices of the European Nuclear Energy Agency, courses were run simultaneously at the Centre d' Etudes Nucleaires, Saclay, France, and at the AERE, Harwell, England. These study courses, restricted to about 50 participants at each centre, were designed to give a broad survey of modern nuclear developments to teachers of science in universities and higher technical colleges. I was fortunate, in spite of a late application, in being accepted for the Saclay course.

No programme could be perfect, but I am sure that, apart from a few defects the Saclay course was an unqualified success.

* * *

One of the most striking features was the large proportion of high ranking personalities, including directors, professors and departmental heads, who had been prepared to give up their working time and even holidays in order to give the lectures. Apart from a few with rather distracting mannerisms, or insufficient preparation, their lectures were highly successful.

Visits to laboratories and major research equipment at Saclay, Orsay and Fontenay-aux-Roses, and to the uranium processing plant at Boucher, left an impression of a healthy nuclear industry, expanding at an exciting tempo. Hardly a square metre of floor space was left unused. Almost all equipment is of French origin, evidence that the country intends to be virtually self-sufficient. Generally, I think, quality was excellent. A few American instruments may be seen, but the salient items of foreign equipment are vacuum pumps and accessories, almost entirely British and German.

* * *

One thing which struck me most forcibly was the almost complete absence of " No Smoking " notices; workers were hectically chain-smoking in every possible situation—reactor rooms, " hot " laboratories, balance rooms, metallurgical labs, and so on. So striking, in fact, was the contrast between French and British ideas in this respect that I could not help wondering which ideology has the sounder basis.

Another feature was the occasional appearance of " La Lutte contre le Bruit " notices. The war against noise seemed to be a forlorn one, however, and it was usually impossible to hear the explanations of the guides. Promises to supply the guides with microphones were not implemented.

* * *

The Windscale incident of 1957 seems to have created a stir in France far greater than in the U.K., and memories have not become dim. Almost every lecturer found reason to mention the accident, though without smug self-righteousness or any bitterness. There were, naturally enough, glances from the audience towards the two British participants whenever the name Windscale cropped up.

'NUCLEARIST'
writes . . .
(from France)

We saw the French equipment for thermonuclear research, but I found this in some ways disappointing having already seen Zeta at Harwell. The huge synchrotron Saturne was very impressive, as were the linear accelerator and the reactors EL-3, Aquilon, Triton and Proserpine, all at Saclay. Generally there is a very close similarity between the nuclear programmes in France and Britain, and I found the French respect British developments very much, a respect which must be reciprocal in fact.

* * *

Although France has at present no plant for uranium isotope separation, there has been intense research on practicable methods, and it looks as if, when the plant is started in the not too distant future, vapour diffusion will be used, just as it is at Springfields. There seems to be little optimism that plutonium will provide the royal road to nuclear power in France, and fast breeder reactors are not envisaged as a large scale possibility in the immediate future.

Production of heavy water in France is based on exchange reactions between water and hydrogen sulphide, although it is recognized that the two-temperature isotope exchange reaction between water and ammonia would be more favourable from the thermodynamic viewpoint.

Although nuclear metallurgy is well advanced, the study of beryllium has not progressed as far as it has in Britain, nor was there much evidence of interest in niobium. The Saclay installation for the study of irradiated fuels is claimed to be the largest and most advanced in Europe. I certainly found it very impressive, but would not like to admit its all-round superiority over the fuel-handling " hot-labs " of Harwell and Dounreay.

The uranium plant at Le Bouchet is very modern, efficient and well instrumented and mechanized. It uses much the same extraction methods as Springfields, with which there is a general overall similarity.

* * *

I was asked many times how, in my opinion, French and British nuclear developments compare. Well, of course, comparisons are odious, and for such a colossal industry, almost impossible. In some respects the British undoubtedly lead, while in others it may be that France excels. On the whole Britain possibly holds the lead as far as fundamental research goes, and most certainly is years ahead of France in the fields of nuclear power generation and nuclear armaments.

* * *

While undoubtedly course participants gained considerable information at Saclay, I am still convinced that even more valuable were the contacts they made with each other and with the French nuclear workers. The advisability of continuing these contacts was stressed during the luncheon which closed the course. The closest possible links between people with nuclear experience and interests must be maintained—the importance of this for international understanding and collaboration cannot be overestimated. It is my personal opinion the ENEA, in spite of its heavy burden of practical projects, should sponsor the closer association of nuclear workers.

The MYTHS of N-Energy

Dr. Chauncey Starr

In the view of Dr. Chauncey Starr, general manager of Atomics International, a division of North American Aviation Inc., American policy and programme planning in the nuclear field has been based on a series of myths, both technical and economic. We print his analysis of some of the technical myths as outlined in a talk he recently gave to the Nuclear Energy Writers' Association in New York. Dr. Starr's talk was called "An Appraisal of Atomic Power Today," subtitled "A Short Introduction to the Mythology of Nuclear Energy."

BY its very nature, a myth is an unsatisfactory basis upon which to plan a programme or policy, and a misleading criterion to use in judging events. Nevertheless, all societies, including our own, have been as much guided and controlled by myths as by natural laws and proven facts. We must recognize that the difference between a fact and a myth is sometimes a shaded one. The intellectual sophistication of the individual is required to discriminate between the two.

Because it is customary for most popular myths to be dramatic, they are often fostered by those in our social and political activities who seek platforms for public appeal. The very salability of a myth to a gullible public has an attraction to the promoter which almost guarantees its promulgation.

We have today many myths that surround our efforts in the development of atomic energy and because they form a part of our daily planning we don't always recognize either their existence or their effect.

The Basic Myth

The foundation myth of the atomic power programme always has been and and still is the assumption that atomic power will some day be less costly than the power from conventional fossil fuel plants. The usual argument presented to support this position is the prognostication that in 25 or 50 years, the limited availability of fossil fuels will raise their costs so high as to eventually make atomic power economically desirable—in fact, economically necessary if we are to maintain the present low cost of electricity. Such " crystal ball " projections depend on now foretelling the energy and fuel situation a half century ahead. Fifty years ago no one could have correctly predicted our energy position today. Because of the uncertainties in such predictions, one must proceed on faith, and hope that this foundation myth will be turned into a fact by future events. There is a good probability that this will be so.

Lower Costs the Aim

The principal technical myth which has pervaded our policy on the development of atomic reactor types has been that there is an ideal technical approach which will eventually lead to the goal of low power cost. As a corollary of this point of view, there have been and continue to be, numerous comparative studies and economic analyses of various atomic plant concepts made with the specific purpose of predicting the lowest cost power producer of the future. Now, unfortunately, the elements of cost which will determine the economics of future atomic power plants involve major intangible areas which cannot be estimated with any degree of accuracy today. Let's examine a few in order of their importance.

1 *Reliability.*—The utility systems in the United States are famous for the reliability of the service which they provide. This means that atomic power plants must equal the reliability of the conventional fossil fuelled plants in order to be operationally acceptable and economically interesting. Power which is not available on a reliable basis has only a marginal economic value to any utility system. It will take many years of continuous operation of many nuclear power plants to establish and prove the reliability of such plants. At present there is a complete absence of substantial data to permit the determination of the relative reliability of the various reactor concepts.

2 *Maintenance.*—It is interesting to observe the economic studies which have been and are still being published concerning the cost of atomic power in relation to maintenance. This cost is usually presented in these analyses as being equal to or fractionally above that for a conventional plant, on a completely arbitrary basis. While such numbers may be reasonable for the routine care of the equipment in the plant, they have no connection with the special costs which will arise due to the failures of the nuclear components of the plant. The costs associated with replacing or repairing a radioactive part of a nuclear plant can be of such magnitude as to make such maintenance costs one of the principal determining elements in the future of reactor development. It is possible to so over-design an atomic power plant as to minimize maintenance costs, but the result of such an approach is to increase its capital cost beyond all acceptable values. There already exists sufficient experience with the experimental reactors presently operating to indicate that this is a major problem.

3 *Fuel Cycle.*—Although it is now well known that atomic fuel has a cost similar to that of conventional fuel, it is not as well known that the total cost of handling this fuel through its complete lifetime is based upon a highly artificial set of administratively set economic conditions. For example, the cost of chemically reprocessing the fuel has been arbitrarily set by the U.S. Government and bears no obvious relation to what these costs might be if an independent chemical industry existed for such purposes. In addition, the use of government supplied nuclear fuel at an arbitrarily set interest rate is a form of financing which can have a very big effect on the total cost of power. As a result, the cost figures used by everyone today are not indicative of what they might be in some future, independent, non-government supported fuel cycle. Even the government prices are set for only a few years ahead.

4 *Natural Uranium* vs. *Enriched Uranium.*—This is perhaps one of the most internationally controversial subjects in the atomic power field. From a technical point of view, there is no question that enriched uranium is a more desirable material than natural uranium. The fact that enriched uranium is predominantly a U.S. monopoly in the free world has stimulated foreign development and construction of natural uranium reactors. As a result of such efforts, many major countries, notably the United Kingdom, have expended great efforts to prove the wisdom of their choice on purely technical grounds. I do not believe this issue will be a major determinant over the long term.

5 *Breeding.*—There has been much discussion concerning the value of breeding as a means of ensuring a large multiplication in the amount of available fissionable fuel. There are many technical authorities who state that unless breeding is successfully accomplished, the development of atomic power plants will not make a major contribution to the future power needs of the world.

I believe this is one of the basic technical and economic myths of our present programme planning. Even if one assumes

(*Continued on opposite page*)

Penetration of Gamma Radiation

Practical experience from N-Explosions

The U.S. National Bureau of Standards has studied the shielding properties of concrete against gamma-ray fallout from two nuclear explosions. Results of this study can be directly compared with established theory and are therefore extremely important in the development of suitable radiation shelters

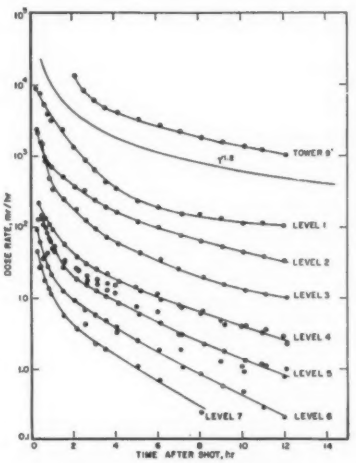
A STUDY of gamma-ray penetration has been conducted by the National Bureau of Standards for the Civil Effects Test Group of the U.S. Atomic Energy Commission. Measurements were made after detonations at the Nevada Proving Grounds, providing on-the-scene experimental data on the effects of fallout.

This study, by W. F. Titus of the Bureau's radiation theory group, is one of the first attempts to make field measurements of fallout in arrangements which lend themselves to a theoretical approach. By allowing an adequate comparison between experimental data and theoretical calculations, this work provides a basis for extending theory to configurations more elaborate than those for which predictions are now possible. Results of this investigation should thus be very useful in the development of suitable shelters against radiation from nuclear explosions.

A central problem of radiation shielding is the prediction or estimation of radiation effects at each point in the shielding material. This problem has been attacked frequently in the past by exposing several thicknesses of absorbent material to a radiation source and monitoring the transmitted radiation. However, these tests have provided the answer to specific shielding questions in complicated configurations only, and it was not possible to extrapolate their results to different conditions.

Simple Geometry

As the propagation of radiation depends in part upon the geometry of the medium, a simple construction would yield results which are more widely applicable. For this reason, the Bureau chose as its test geometry an infinite plane uniformly covered by fallout. A calculation of the penetration for this simplified situation, which is in effect an infinite homogeneous medium exposed to a plane-isotropic source, had been previously worked out by the radiation theory group. This calculation formed the theoretical basis with which experimental results were compared.



Graph showing the decrease in dose rate with time at 9 ft above ground (tower) and at seven levels within a concrete mass. These results were obtained in an experimental study of gamma-ray penetration in concrete by the National Bureau of Standards. The time dependence of dose rate above ground is seen to be $t^{-1.2}$, indicating that the fallout measured is typical for a nuclear explosion

Concrete, one of the materials most suitable for shielding applications, was the medium chosen for study. Penetration was experimentally determined in a stack of seven reinforced concrete slabs, constructed in a pit, 8½ ft square and 40 in. deep. Geiger counters inserted into spaces

N-ENERGY MYTHS—*Continued from opposite page*

optimistic projection concerning the development of breeders and their incorporation into the atomic power programme, the amount of fissionable fuel that would be required for the growth of atomic power would be reduced by only a fraction. For example, under the most optimistic conditions at the end of the next 50 years the total amount of fuel needed might be reduced by as much as one-third through the utilization of breeders. From an economic point of view, the justification for breeders is extremely doubtful. Large parts of the fuel cycle for breeders have no basis for any kind of economic evaluation other than a certainty that they will be very costly.

6 *High Temperatures.*—Within the utility industry one of the most commonly accepted technical myths is the value of high temperature steam conditions for power generation. This has become a " philosophic gimmick " and a technical prestige goal for the engineers of the utilities. The growth of this myth has resulted from the fact that the efficiency with which conventional fuels are used does increase as the temperature of the power plant goes up. However, the over-all purpose of the development of power plants is the reduction in cost of electricity. If the increase in temperature results in a more expensive plant, its benefit may disappear.

It does not necessarily follow that lower power cost will come from high temperature if equipment costs increase as a result. This situation is particularly pertinent to the present state of atomic reactor technology where all the high temperature concepts are at present exceptionally expensive. It is interesting, therefore, that within the utility industry the high temperature myth has caused automatic acceptance of reactor concepts with a high temperature potential, without the industry's customary cautious examination of over-all economics.

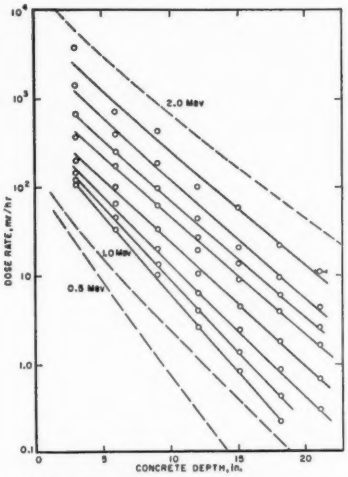
between the slabs measured the dose rate as a function of depth. The total dose accumulated at each level was monitored by pocket or film dosimeters. In addition to the detectors within the concrete mass, detectors were mounted on a steel tower 20 ft from the pit.

Decimal Increases

At almost all times the dose rate under 2 in. of concrete was found to be approximately $^1/_{10}$ that at 9 ft above the ground. Each additional 6 in. of concrete reduces dose rate by another factor of approximately $^1/_{10}$. The over-all attenuation in 22 in. of concrete is therefore about 1 ten-thousandth of the dose rate at 9 ft above the ground. This experimentally observed decrease in dose rate with depth shows good agreement with the calculated decrease in dose rate for an ideal situation.

The detection system was a remote radiation-monitoring system designed by the Bureau. Dose-rate detectors were connected with equipment in nearby underground vaults. From these underground stations, data were transmitted by direct field lines to a control point where information was automatically checked and catalogued.

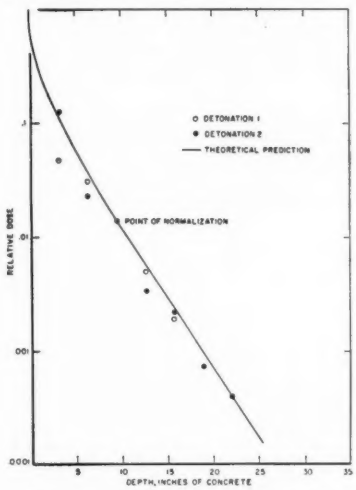
Experimental data were obtained in this way after each of two nuclear explosions. Immediately after the test shot, dose rates were measured in the various levels of the concrete and at the tower. Measurements were made every 12 min during the first 2 hr, then every $\frac{1}{2}$ hr for the next 3 hr, and finally every hour until the dose rates in the lower levels were below 1 mr/hr. These measurements were performed at 2,000 yd from one nuclear test shot and 4,000 yd from the other.



National Bureau of Standards' measurements of gamma-ray penetration in concrete show that during the first few hours the fallout penetration is similar to that of 2 MeV plane isotropic source. Later the penetration resembles that for a 1 MeV plane isotropic source, indicating the loss of faster decaying high-energy components from the gamma spectrum

Results of this work indicate that the time dependence of the dose rate above ground is $t^{-1.2}$, which is in agreement with precise dose-decay measurements made elsewhere in the area. The fallout incident on the concrete is therefore considered typical. The dose rate under 9 in. of concrete decreases more rapidly with time than this surface dose rate during the first 10 or 12 hr after the blast. This decrease is probably due to the more rapid decay of the higher energy components of the gamma spectrum at the surface.

During the first few hours, the penetration of fallout radiation is very like that of a 2 MeV plane isotropic gamma source. At later time, penetration falls off, resembling a 1 MeV plane isotropic source.



Comparison between theoretical calculations and experimental data for the penetration of gamma radiation in concrete. The experimental values, which have been normalized to the calculated curve at a depth of 9.5 in. show a good agreement with theory. This comparison by the National Bureau of Standards shows the conditions 1hr after a nuclear detonation

RESEARCH AT SLOUGH

(*Continued from page 501*)

that of the can up to 4½ in. An electrical resistance method of heating the cans provides a maximum rating of 23.3 to 190 kW/ft dependent upon the fuel elements under test, and the power dissipated can be varied for individual channel sections.

The design and construction of the equipment with its complete system of instrumentation and controls enables accurate assessments of performances to be made over a wide range of operating conditions. The equipment is available for use by other organizations for operation by their own staff if desired with the aid of Hawker Siddeley technicians. Currently the apparatus is being used for making a series of investigations on behalf of a Swedish company.

Among other facilities of the Hawker Siddeley Nuclear Power Co., are a 22,000 Joule Condenser Stack which is being used for the development of high current control equipment, the design of a mercury safety device for thermal reactors, and the development of a plasma jet capable of reaching temperatures up to 10,000 °C., which it is proposed to use for testing graphite jet nozzles.

Computing Service

Vital for the carrying out of research is access to an efficient high speed computing service. Hawker Siddeley are equipped with an analogue computer of their own design, two Ferranti Pegasus computers and two Ferranti Mark 1 digital computers, backed by comprehensive auxiliary equipment including programmers, tape editors and calculating machines. With this equipment the company are able, not only to deal with their own research problems, but also to offer a service to other organizations.

Hawker Siddeley may not have been in the limelight of nuclear engineering as much as companies associated with the gas-cooled graphite moderated reactor system have been, but there is no doubt that the company is just as well equipped and as well advanced to cope with the problems involved in its chosen sphere of activities.

PEOPLE... in the NUCLEAR NEWS

For two years the manager of overseas atomic projects of the English Electric Co., Ltd., **MR. J. F. HERBERT** has now been appointed general manager of export sales. He will continue his responsibilities in the nuclear field. Also a director of the English

Mr. J. F. Herbert

Electric Export and Trading Co., Ltd., Mr. Herbert has been with English Electric since 1930, when be became a graduate apprentice at the company's Rugby and Stafford works following a university education in Australia. After a period as personal assistant to the general manager of the works and then further training at Edinburgh, Mr. Herbert worked for a year as the company's representative in the eastern counties. At the end of 1934 he was sent out on a sales mission to West Africa and, after further service in London, was appointed the company's technical representative for Malaya. On the outbreak of war he was commissioned in the local volunteer forces in Malaya, and was taken prisoner in Singapore when that city fell in February, 1942. In 1945 he returned to England, and two years later returned to Singapore as manager (Far East) for the company, in which post he remained until 1953 when he returned to the United Kingdom on his appointment as export area manager for Australasia and the Far East.

The Central Electricity Generating Board have appointed **MR. G. C. DALE,** BSc, of the Atomic Weapons Research Establishment, Aldermaston, deputy physicist in their nuclear health and safety department. Mr. Dale, who is 38 years old, graduated at London University and was for a few years in the radiology department of the National Physical Laboratory, Teddington. In 1949 he joined the Ministry of Supply as a member of the department which subsequently became the AWRE health physics division.

AIR CHIEF MARSHAL SIR CLAUDE PELLY, GBE, KCB, MC, who is Member (Designate) for Weapons of the United Kingdom Atomic Energy Authority, is no newcomer to the administrative side of research and development. He was at one time commanding officer of the Ministry of Supply's Aeroplane and Armament Experimental Establishment at Boscombe Down, Wiltshire. At present he is Controller of Aircraft at the Ministry of Supply. Born at Malvern in 1902 and educated at Rugby School and the RAF College, Cranwell, Sir Claude was awarded the Military Cross in 1933 while serving in Iraq. At the outbreak of the war he went to France as an Air Staff intelligence officer at the headquarters of the RAF Component Field Force. After the evacuation he held various staff appointments in the United Kingdom until December, 1940, when he went to RAF Middle East headquarters on Air Staff planning duties. In 1943 he became senior Air Staff officer at Air Headquarters, Western Desert, and after returning to the United Kingdom towards the end of that year, served for a short time in the department of the Chief of the Air Staff before joining the headquarters of the Allied Expeditionary Force on Air Staff planning duties in May, 1944. Afterwards he was for a short period director of operations at the Air Ministry, before being appointed head of

Sir Claude Pelly

the British Bombing Survey Unit formed by the Air Ministry in November, 1944, to investigate the effect of the Allied bombing offensive. Later, when the unit grew into what was known as the Inter-Departmental Bombing Survey, he became head of the RAF element. The survey covered almost every part of Europe outside the Russian Zone and Air Marshall Pelly served with it until he was appointed commanding officer of the experimental establishment at Boscombe Down. In 1948 he became Assistant Chief of the Air Staff Operational Requirements. In December, 1951 he became RAF Instructor at the Imperial Defence College. In January, 1957, he was appointed ADC to the Queen. In his appointment to the Authority, Sir Claude succeeds **SIR WILLIAM PENNEY,** who becomes the new Authority Member for Scientific Research in place of **SIR JOHN COCKCROFT,** OM, FRS.

MR. JOHN B. ADAM, who will be head of the Atomic Energy Authority's new establishment dealing with controlled thermonuclear research, is at present director of the proton synchrotron group of the Central European Council for Nuclear Research (CERN), Geneva. He will take up his appointment with the Authority towards the end of 1960, when the location of the new establishment will have been decided. During the war, Mr. Adams, who was born in 1920, worked in at the Telecommunications Research Establishment of the Ministry of Aircraft Production on the development of centrimetric radar. He went to the Ministry of Supply during the early days of the Atomic Energy project and from 1946 to 1953 worked at Harwell, where he was a member of the team that designed and built the 110 in. cyclotron. He joined CERN in 1953.

MR. K. FEARNSIDE has been appointed to the board of Smiths Aircraft Instruments, Ltd., as director of research. He was formerly research manager at the company's Cheltenham factory. From 1946 to 1950 Mr. Fearnside was at the Atomic Energy Research Establishment, Harwell, where he did work in basic nuclear physics and the application of radioactive isotopes for industrial purposes. He then became technical director of a newly-formed company, Isotope Developments, Ltd. He joined Smiths in 1953.

Joining the ranks of eminent scientists and engineers who have received the John Fritz Medal, the annual American award for outstanding scientific and industrial achievements, is **MR. GWILYM A. PRICE,** chairman of the Westinghouse Electric Corporation. He receives the award for " inspirational leadership, industrial pioneering and personal initiative in marshalling the creative forces of research and engineering to the cause of developing atomic power for national defence and for the human welfare." Westinghouse, under the chairmanship of Mr. Price, have been responsible for the design and construction of the reactor plants installed in U.S. Navy nuclear submarines and in the surface vessel *Long Beach*, also and in the generating plant at Shippingport, Pa. Westinghouse are currently building the 134 MW Yankee power plant and the 11,500 kW BR-3 plant for Belgium. Mr. Price is the first recipient of the John Fitz Medal without an engineering background. First awarded in 1902, the medal has previously been given to such men as Lord Kelvin, Alexander Graham Bell, Thomas Edison, Orville Wright, and Herbert Hoover. Mr. Price, who was born in Canonsburg, Pennsylvania, in 1895, is lawyer, banker and industrialist. A graduate of the Pittsburgh University's Law School, he was first a trust officer of a bank and served a term in the State Legislature. In 1937 he was elected president of what is now the Peoples First National Bank and Trust Co. He joined Westinghouse as a vice-president in 1943, was elected president in 1946 and chairman of the board in 1955. He is also the president of the board of trustees of Pittsburgh University, and chairman of the Crusade for Freedom Inc. He also serves on several advisory councils and the boards of a number of banks and corporations, as well as being a trustee of the New York Carnegie Corporation.

NUCLEAR NEWS

- **U.K.A.E.A. Factory Contract** *(First Story)*
- **Thorium-Sodium Reactor** *(Page 513)*
- **Consortia Combine** *(Page 514)*

HAWKER Siddeley Nuclear Power Company Ltd. are to operate the United Kingdom Atomic Energy Authority's factory at West Howe, near Poole, Dorset. Working in close conjunction with the Atomic Energy Establishment, Winfrith, they will design, manufacture and test reactor engineering equipment for the Authority.

O.E.E.C. Convention

THE OEEC Convention on the establishment of a security control in the field of nuclear energy, which is designed to ensure, in particular, that joint nuclear facilities developed with the help of the Organization are used exclusively for peaceful purposes, has entered into force. The Convention was signed by all OEEC member countries on December 20th, 1957. The ten countries which have now ratified it, so bringing it into force, are (in order of notification) the United Kingdom, Ireland, Switzerland, Norway, France, Denmark, the Netherlands, Turkey, Germany and Belgium. The operation of the control system specified in the Convention will be the responsibility of the OEEC European Nuclear Energy Agency. This control is based on inspection of plant and the maintenance of accounts of all fissionable materials used or produced, and ENEA's first task will be the preparation of control regulations and the setting up of an international control bureau, including the appointment of an international inspection team.

Huge Backlog to Work Off

TRACERLAB, Inc., leading American manufacturers of nucleonic instrumentation and X-ray equipment, have announced a loss of $227,000 for the first six months of 1959. Expenditures for development and sales effort were $154,000 in excess of that spent during the first six months of 1958 and as a result, Tracerlab have a backlog of $3½m. worth of orders, highest in the company's history. The company plans to reduce this backlog during the remainder of 1959 and so make a small profit for the whole year.

Isotope Guide

THE first volume of an "International Directory of Radioisotopes—Unprocessed and Processed Radioisotope Preparations and Special Radiation Sources," containing information on all radioisotopes which are for sale or distribution by the 59 major suppliers in the world, has been published by the International Atomic Energy Agency. The 264-paged Directory contains tables of radioisotopes, including processed and unprocessed isotope preparations, and solid radiation sources for special applications; the most important physical data, such as half-lives and radiation; some details of preparation and specification of individual preparations; lists of all present suppliers indicating the range of their services, as well as of countries which intend to manufacture isotopes in the near future, and, finally, a guide on the safe handling of radioactive materials. Volume II of the "International Directory of Radioisotopes" containing complete information on the labelled compounds of C-14, H-3, I-131, P-32 and S-35 will follow shortly.

New French N-Centre

AN additional large nuclear research centre is to be built at Cadarache in the Department Bouches-du-Rhône, France, by the French Atomic Energy Commission. With Fontenay-aux-Roses, Saclay, Grenoble and Marcoule, this will bring the number of French nuclear research centres to five. The Cadarache installation will be constructed at a cost of about Fr.20,000m., and is destined for investigating the improvement of existing types of reactors, especially the graphite-moderated type and the experimental reactors "Pegasus" and "Brenda" will be designed for this purpose. The pool-type "Pegasus" will be experimented with nuclear fuel elements to be used in gas-cooled power reactors. This is the type of reactor which Electricité de France is constructing or planning to erect. "Brenda" will be designed to utilize enriched uranium as fuel and is intended for operating at the high temperatures which may make it feasible to employ gas turbines for the production of electric power. The third reactor to be installed at Cadarache has been named "Rhapsody" and will be the fast-neutron type, cooled by liquid sodium.

Oil Odour Reduced

SHELL-MEX and B.P., Ltd., are now marketing a range of improved soluble cutting oils—Shell DROMUS soluble cutting oils. These reformulated grades contain an improved coupling agent to facilitate the formation of a stable emulsion when the oil is mixed with cold water, hard or soft, with the result that the oils do not now possess the odour of disinfectant normally associated with soluble cutting oils. This makes them more acceptable, particularly to women operators. In addition, the absence of the conventional phenolic coupling agent reduces the tendency of the emulsion to cause irritation of tender skins.

Moderator the Control

A VARIABLE moderator reactor (VMR) concept in which the reactor is controlled by adjustment to the level of the moderator rather than by mechanical manipulation of neutron absorbing control rods is to be evaluated and tested for the U.S. Atomic Energy Commission by the Advanced Technology Laboratories, a division of American Standard. The VMR, which will use light water as moderator, will be tested in its critical state at the Battelle Memorial Institute. American Standard are also to investigate for the USAEC means of improving the radiation stability of natural uranium metal. A further project is a study of how to reduce nuclear fuel costs through the application of high temperature spray techniques to form clad ceramic fuel elements.

Co60 Machines for China

FOUR more cancer treatment machines together with their Co60 radiation sources have been shipped to the People's Republic of China by Atomic Energy of Canada, Ltd. The shipment is valued at $180,000. Two cancer treatment machines were purchased from Canada by China last January. It is estimated that the six machines will provide 5,000 treatments each month to cancer patients. AECL have now shipped 160 cancer therapy machines to 27 countries; the total value of these units and their radiation sources is about $7m.

Savannah Simulator

MERCANTILE marine officers who will be in charge of *N.S. Savannah* are now undergoing special training at Lynchburg College, Virginia, U.S.A., where the Westinghouse Electric Corporation have built a reactor propulsion plant simulator. This consists of a control console, instructor's control desk, analogue computer and auxiliary cabinet. All possible operating conditions of the reactor installed in the *Savannah* can be simulated and the controls are a replica of those which will be found in the actual ship.

I.N.E. Election

BALLOT papers for the election of the Council of the Institution of Nuclear Engineers have been circulated to members. There are 15 candidates for the 12 seats available on the Council. The date of the Institution's inaugural meeting will be fixed shortly after the results of the election are known.

Fully Booked

ALL floor space at the International Fair for Laboratory, Measuring and Automation Techniques in Chemistry to be held in the Swiss Industries Fair Building at Basle from November 10th-15th has been taken. There will be 262 exhibitors representing Belgium, Denmark, Germany, England, France, Holland, Italy, Austria, Sweden, the U.S.A., and Switzerland.

Export Orders

THREE further orders, worth about £40,000, have been received for the heavy-duty power-operated manipulator specially developed by The General Electric Co., Ltd. Each of the three machines, one for Japan, one for Sweden, and the other for Harwell, is to be used for the remote handling of irradiated nuclear-reactor fuel elements. Japan's manipulator is for the Japan Atomic Energy Research Institute which is at Tokai-Mura, close to the site where GEC is to build the country's first nuclear power station. The Swedish order was from AB Atomenergi—the Swedish Atomic Energy Co.—an organization owned jointly by the State and a number of private and municipal interests. The manipulator will be installed at the Studsvik Research Station, near the Baltic, 60 miles south of Stockholm. The manipulator for the Atomic Energy Research Establishment at Harwell is the second of these machines to be ordered by the U.K. Atomic Energy Authority. The first one is to be installed at the Windscale establishment of the Authority's Industrial Group.

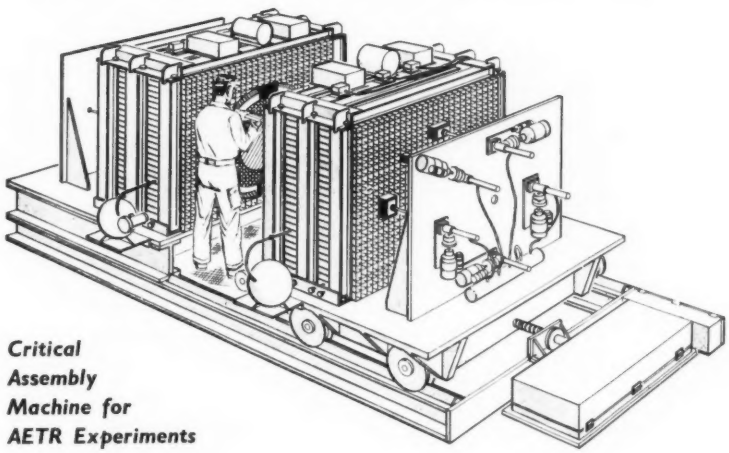
I.A.E.A. Laboratory

THE United States has contributed $600,000 to the International Atomic Energy Agency for the building and equipping of a functional nuclear energy laboratory at Seibersdorf, near Vienna, Austria. The laboratory will be a one-storey brick and reinforced concrete structure adjacent to the site of the Austrian Nuclear Centre (Studiengesellschaft fuer Atomenergie-SGAE) where work is in progress on a research reactor. The Agency will have access to the Austrian reactor in carrying out its laboratory work, and research workers of the Austrian Nuclear Centre will be able to use the Agency's laboratory. Among the activities of the laboratory will be: standardization of radioactive sources, the establishment and study of international standards for measurement techniques, the calibration of equipment and its adaptation for use in various countries, and measurement and analyses in connection with the Agency's safeguards and health and safety programmes.

At Lucas Heights

Recent visitor to the Australian Atomic Energy Commission's nuclear research establishment at Lucas Heights, near Sydney, was the Governor-General of Australia, Field Marshal Sir William Slim. He is seen here (*hat in hand*) on his arrival at the station with the AEC chairman, Professor J. P. Baxter (*left*), and the Executive Commissioner, Mr. A. D. McKnight

Preparing for Thorium-Sodium Reactor



Critical Assembly Machine for AETR Experiments

Current project of Atomics International Inc., a division of North American Aviation, Inc., is the study and design of the Advanced Epithermal Thorium Reactor (AETR) with a view to the construction of one or more full-scale power plants utilizing this reactor concept. In the AETR it is planned to use sodium as coolant, a thorium-uranium alloy as fuel, and beryllium or graphite as moderator. The first nuclear power plant would be rated at 360 MW(e). First phase of the project was completed in June and consisted of conceptual design and analytical studies of possible core and blanket configurations to determine the engineering problems, performance requirements and economic potential of the AETR. The second stage of the project will be taken up with tests of mock-up reactor cores to study the effects of reactor materials on nuclear chain reactions and so determine the best design for the AETR core. The tests will be made in a critical assembly machine (*illustrated above*) which is basically a square honeycomb structure divided into two sections, one of these being movable. Reactor fuels and materials will be inserted in square metal tubes forming the honeycombs. The two sections will then be brought together, the assembly becoming critical and the accuracy of theoretical data developed in the first stage of the project checked

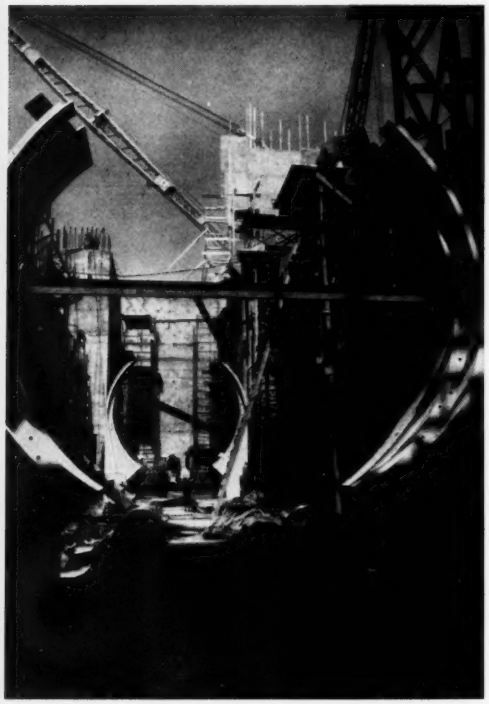
Eximbank Loan

THE Commission of the European Atomic Energy Community and the Export-Import Bank of Washington have signed agreements implementing the Bank's $135m. line of credit to assist in financing the construction of nuclear power plants to be built under the Joint United States-Euratom Programme in the Community countries. The goal of the Joint Programme is a total installed generating capacity in the nuclear powered plants of approximately 1m. kW. In addition to nuclear power development, the United States-Euratom Agreement provides for a programme of nuclear research and development to be carried out simultaneously for the six countries in co-operation with the United States, in both the Community and the United States. The total cost of the power plants is estimated at $350m. The $215m. required in addition to the Eximbank loan will be raised from European sources.

Isotopes, Tokyo

SCHEDULED for completion by December is Japan's first isotope laboratory, the Metropolitan Isotopes Centre, in Komazawe, Tokyo. Equipment installed here will include a Van de Graaf accelerator, a 15 MeV betatron, and 5,000 c Co60 radiation equipment. Among work carried out will be chemical, biological and engineering research using tracers. Staff will number 150.

N.P.D. Progress



A view of part of Canada's first nuclear power station under construction near Rolphton, Ontario. Known as NPD (Nuclear Power Demonstration), the plant is scheduled for completion in 1961, when it will send out 20 MW into the electricity distribution system. It is a prototype for larger plants fuelled with natural uranium and moderated with heavy water

N-Fire Safety Report

THE South Western Scottish Fire Area Joint Board is to prepare for its members a report on the capabilities of local fire brigades to deal with incidents involving hazards from nuclear energy installations and equipment. The Board feel the public should know what protection the fire services could offer in this field, particularly in view of the fact that there would soon be two nuclear power stations operating in the area and U.S. aircraft flying from Prestwick would be carrying nuclear armaments.

Be. Output Grows

DELIVERY of reactor grade beryllium metal to the U.S. Atomic Energy Commission is being made at a rate greater than called for in its AEC contract according to The Beryllium Corporation. The company holds a five-year contract to supply a total of 187,000 lb of beryllium metal billet at the rate of approximately 37,000 lb/year, and has constructed a completely integrated plant at Hazleton, Pa., to fill all these requirements. While the original government contract for beryllium metal billet was intended solely for the purpose of nuclear end use, recent rapid developments in the use of beryllium by the aircraft and missile industry has required the diversification of a continuous part of production to Defence Department application. The Beryllium Corporation recently completed an enlarged facility for fabricating beryllium components for both nuclear and aircraft-missile type parts and indicated that a substantial portion of its billet production will be diverted to the production of components in the future. The corporation recently announced plans to join with Imperial Smelting Corporation, Ltd., of London, in the formation of a British metals company, Consolidated Beryllium, Ltd. The latter has started designing what will be the largest beryllium metal plant in the world when demand develops.

Super Efficiency Aim

A $2.7m. (nearly £1m.) study proposal by U.S. General Electric for increasing the efficiency of nuclear power plants by superheating steam has been selected by the U.S. Atomic Energy Commission for contract negotiations. General Electric began the first American production of nuclear superheated steam in a company-financed experiment earlier this year. So far the experiment has produced steam at 825°F. and 930 lb/sq.in. gauge. The proposal was one of two selected by the AEC from among nine submitted to the Commission by various companies. The objective of the study, which will be conducted at General Electric's San Jose (California) and Vallecitos Atomic Laboratory (Pleasanton, Calif.) facilities, is to investigate methods to add more heat to the steam produced by water-type nuclear reactors. Currently, these reactors produce steam in a saturated form. An increase of nuclear fuel in the core of the nuclear plants simply generates more saturated steam.

Consortia Combine

AMONG tenders submitted to the Central Electricity Generating Board for the construction of the Dungeness nuclear power station will be a joint offer from the Nuclear Power Plant Co., Ltd., and the AEI-John Thompson Nuclear Energy Co., Ltd. These two consortia are also planning to submit a joint tender for the Sizewell station. Both groups are already building, separately, nuclear power stations, the NPPC at Bradwell, Essex, and at Latina, Italy, and the AEI-JT Co. at Berkeley, Gloucestershire.

Nuclear Lectures

LECTURE courses on nuclear physics and nuclear engineering are being offered during the autumn session of the South East London Technical College, Lewisham Way, London, S.E.24. The aim of the nuclear physics course is "to provide an adequate knowledge of nuclear physics and its application in general to enable the student to read intelligently the publications in the field of engineering." The course on nuclear engineering is of a more advanced nature. Further details can be obtained from the head of the electrical engineering and applied physics department.

Helping the Exporter

To assist firms in starting up an export business the Gauge and Tool Makers' Association have issued a booklet giving useful information on overseas trading. Called "A Simple Guide to Prospective Exporters," the booklet deals with representation in foreign markets, how to appoint an agent, methods of exporting, methods of payment, documents required by exports and exporters, etc. The book costs 3*s.* 6*d.* and is available from the association offices, Standbrook House, 2-5, Old Bond Street, London, W.1, post free.

TRAWSFYNYDD

(*Continued from page 490*)

large amount of rock blasting. There are also a large number of boulders and great quantities of peat to be removed.

Work on the site started in July, 1959. The station is scheduled to be fully operational by 1964.

Trawsfynydd is being built for the Central Electricity Generating Board by Atomic Power Constructions Ltd., the consortium formed at the end of 1956 by Crompton Parkinson Ltd., Fairey Aviation Ltd., International Combustion (Holdings) Ltd., and Richardsons Westgarth & Co., Ltd. Civil engineering work is being undertaken by Nuclear Civil Constructors, a partnership formed by Trollope & Colls Ltd., and Holland & Hannen and Cubitts Ltd., specially for nuclear work.

Also associated with the Trawsfynydd project is Babcock & Wilcox Ltd., who are to build the two reactor pressure vessels and a 400 Goliath crane to be used in the construction of the station. This will be almost identical in design to the Goliath Babcock and Wilcox have built for use at Hinkley Point.

The contract for the station is Atomic Power Constructions' first. They won it in the face of competition from consortia already building nuclear power stations and with many more years experience in designing nuclear projects. It is to their credit that they were able to submit a tender that not only met with the Generating Board's requirements, but which was also the lowest priced.

Equipment and Materials

Items published in this monthly feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

Temperature Control

Co-operation between the laboratories of United Steels Ltd., and Winston Electronics Ltd., has resulted in the commercial production of the Winston-United Steels Temperature Controller Type M.226 This robust and accurate instrument, which can be used with temperatures of up to 1,200°C, was designed as a result of investigations into the problem of critical temperature control of furnaces used in the creep testing of alloy steels. It has many other applications. Through the use of improved multi-turn potentiometers the controller gives direct calibration of the operating temperatures. The furnace switching relay has no other circuit function to perform and so avoids the critical adjustment of a normally troublesome component. The control of oil or gas furnace is achieved by using a suitable magnetic valve. A mercury or vacuum switch may be fitted where greater current output is wanted. **(OC 1)**

Plastic Protection

Clear housings moulded of tough Tenite butyrate plastic help protect delicate meters for portable scientific equipment from the rough handling such apparatus must frequently encounter. At the same time, the transparency of the butyrate permits meter faces to be seen clearly and read without distortion. Furthermore the butyrate adds little to the weight of the instruments. Among its users are Universal Atomics, a division of Universal Transistor Products Corp., of Westbury, Long Island, manufacturers of portable radiation detection equipment. The housing units for their equipment are made by Fischer Plastics, of Burbank, California, where the Tenite butyrate is supplied by Eastman Chemical Products Inc., of New York. **(OC 2)**

Radiation detection apparatus and an ammeter contained in protective housing units made from Tenite butyrate plastic

Clothing Storage

Five hundred industrial lockers for protecting the clothing of employees were recently installed at the Windscale nuclear energy plant. The lockers are a similar model to those also recently supplied by the makers—Vernons Industries Ltd., Kirkby, Liverpool—to the National Coal Board for use at pit-head baths. In all, over 500,000 of the lockers have been sold to industry. The lockers, which are constructed so that 12 can be erected in 1 sq.yd, are made from Zintec. This a sheet steel coated with pure zinc electrolytically deposited on the surface. It is produced by John Summers & Sons Ltd., of Shotton, Chester. The lockers can be heated by steam, electric or plenum systems. **(OC 3)**

Clothing lockers as supplied to the UKAEA, Windscale

For Small Quantities

A new semi-automatic liquid scintillation counter is now available from Tracerlab, of Massachusetts. The instrument is specifically designed for colleges, universities and other research facilities in which precision analysis of low energy beta emitters (i.e., C14 and H3) have to be performed in quantities not requiring complex automatic sample changing systems. The LSC-10 liquid scintillation counting system, as it is called, consists of a compact top-opening deep freeze unit which contains the semi-automatic sample changing equipment, and a 4 ft instrument console containing the associated electronic circuitry. A combination of low background and high efficiency provide a sensitivity that is not surpassed even by more costly instrumentation. Thus, extremely low concentrations of carbon or tritium can be counted in minimum time. The sample changer holds forty 20 ml glass sample vials. Once loaded all samples are counted without reopening the freezer. Samples are changed by means of externally operated control knobs. **(OC 4)**

Cut along here

To: **NUCLEAR ENERGY ENGINEER**
147 Victoria Street, London, S.W.1

Please send further details of the following items in the EQUIPMENT and MATERIALS *feature for October, 1959*

Item No's ....

....

IS THIS ENQUIRY CONFIDENTIAL? YES | NO

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Position .....

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INSULATION AND STRENGTH

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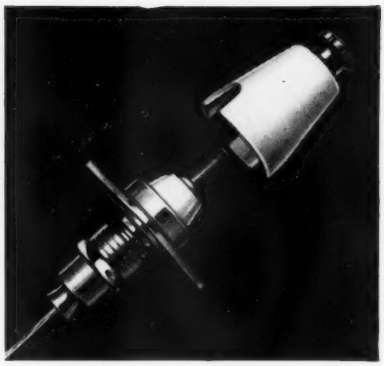

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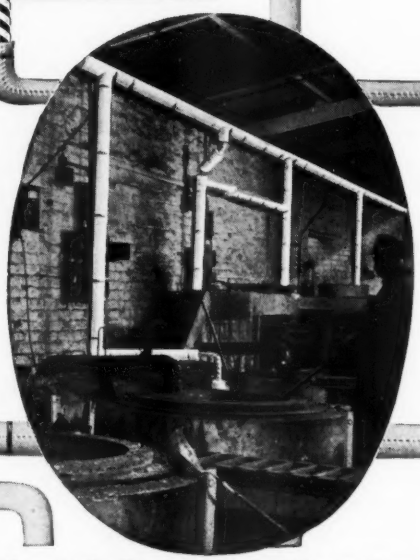

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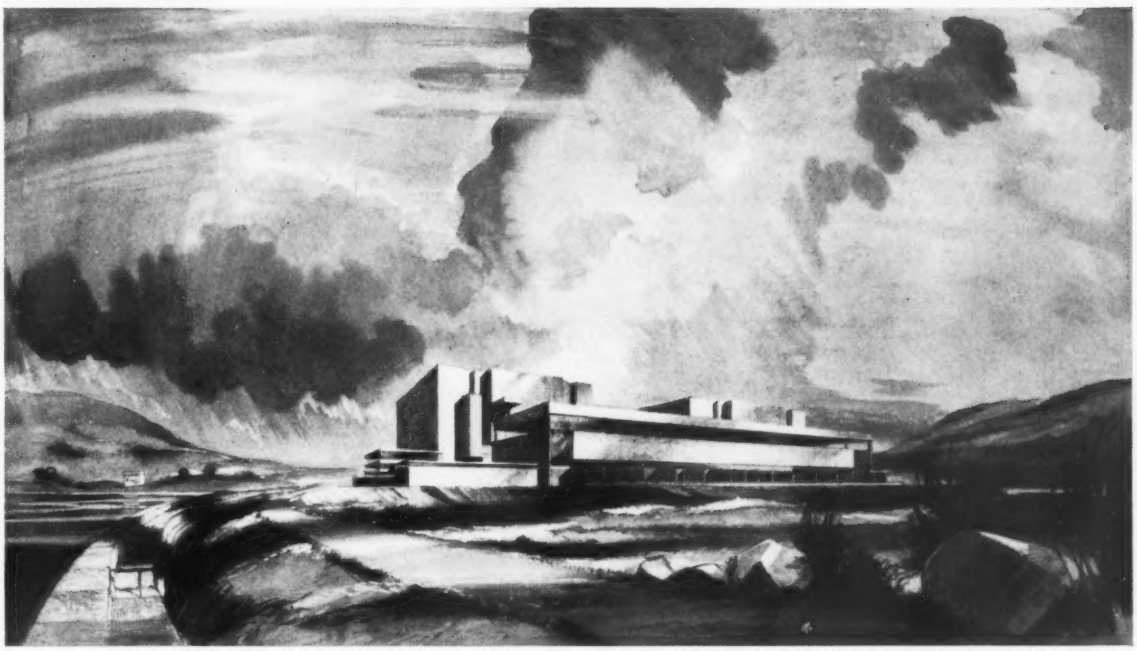
Trawsfynydd

NUCLEAR POWER STATION



This impression of Trawsfynydd Nuclear Power Station by Mr. Basil Spence ARA, *President* RIBA, *consultant architect to Nuclear Civil Constructors, shows how the design blends with the landscape of Snowdonia.*

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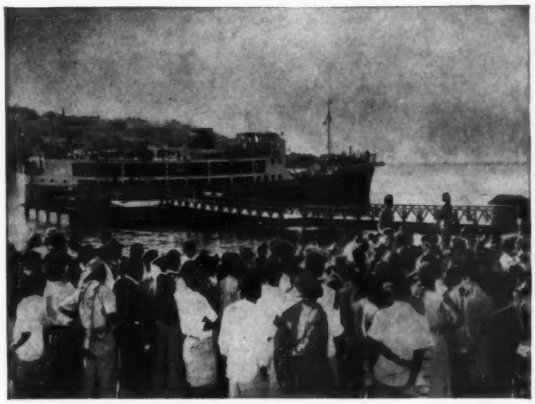

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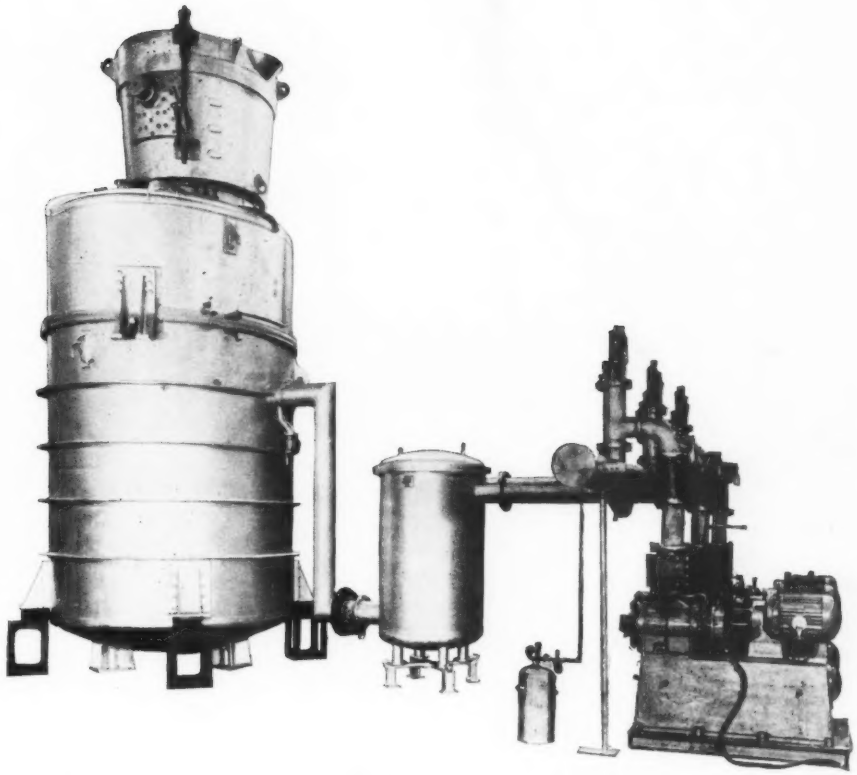

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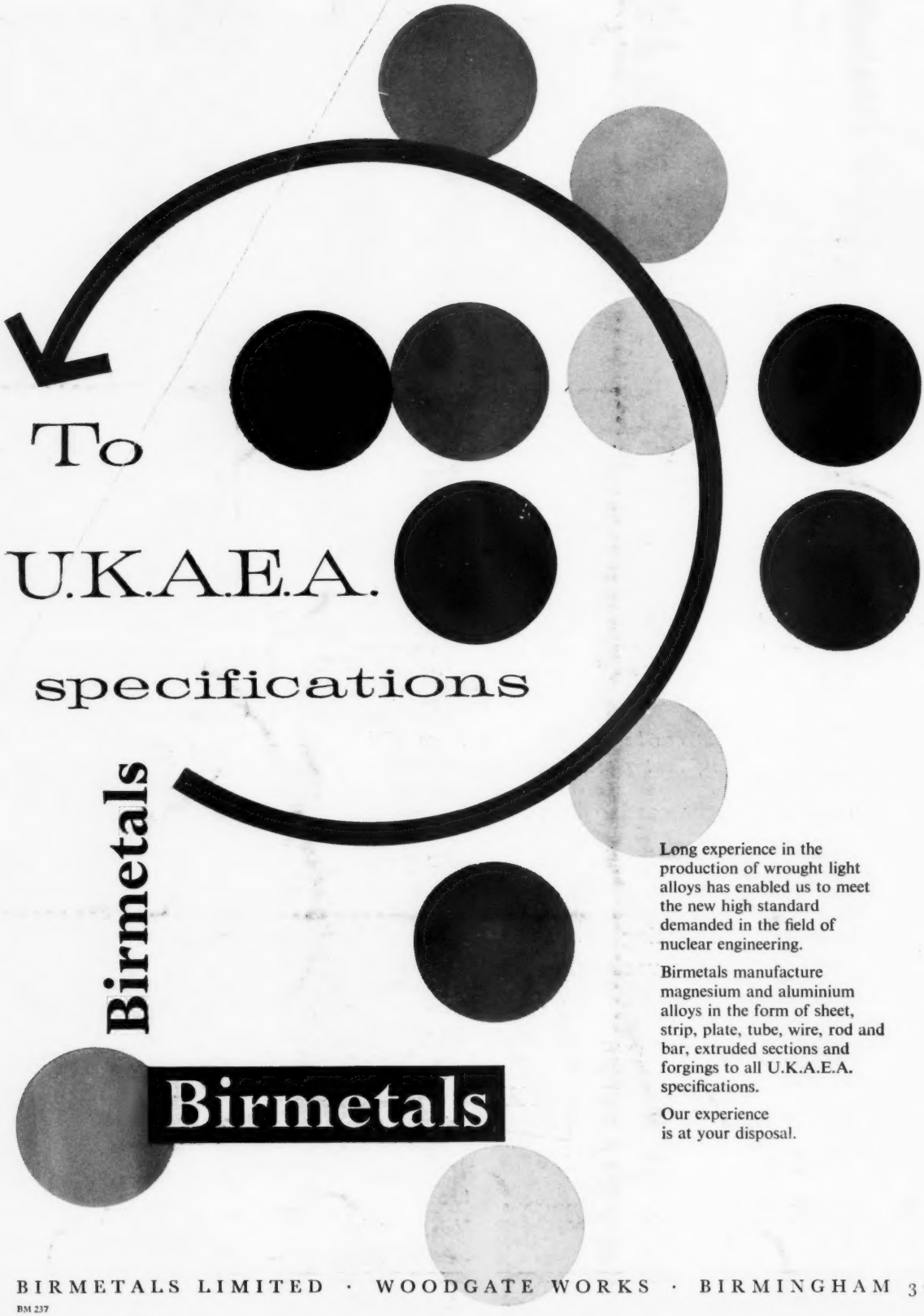

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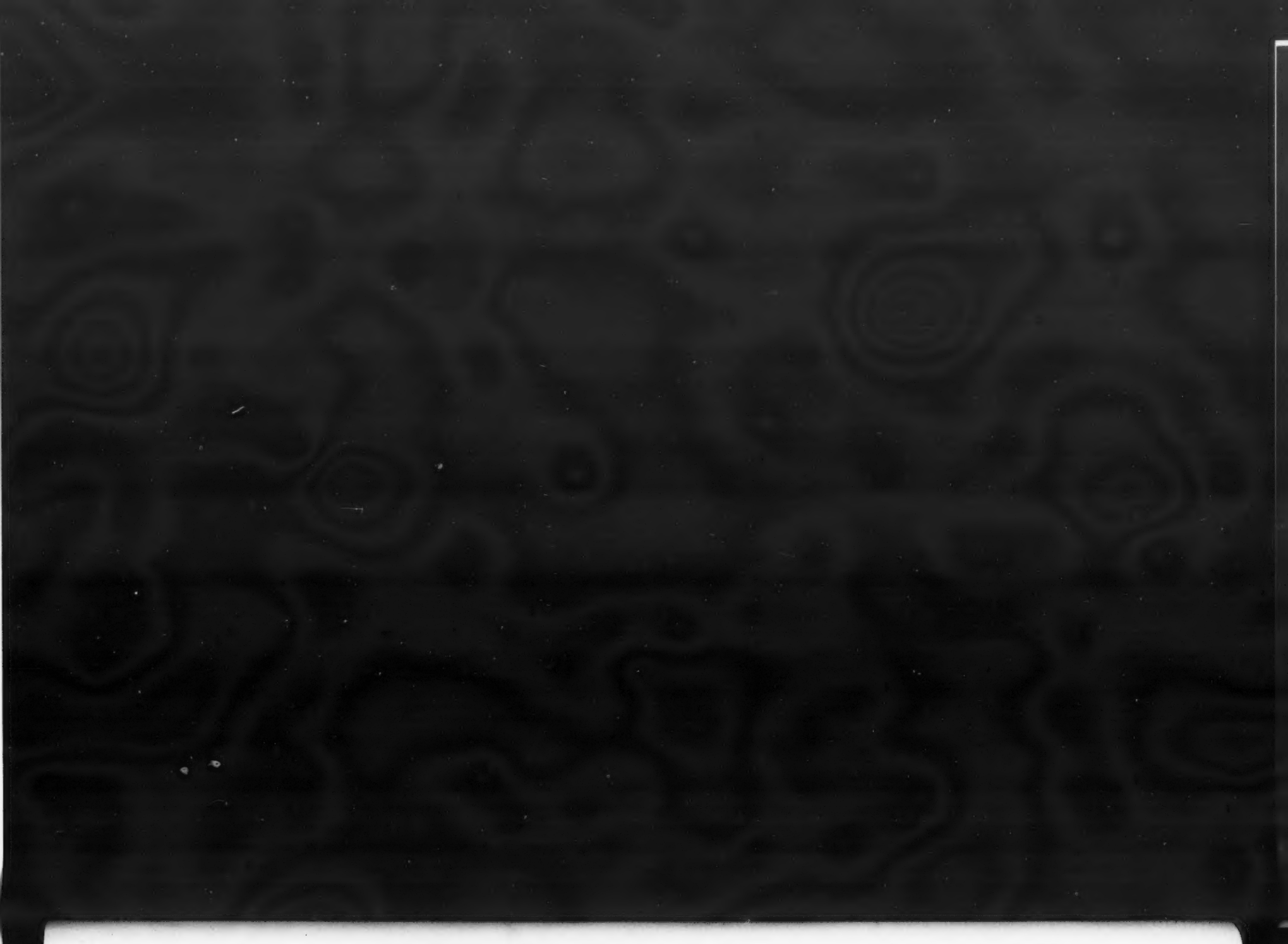
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